Applying and evaluating 3D Bodyscanning Technology and landmarking within the clothing product development process to improve garment fit for mature women aged 55+

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Quote

‘I wanted to give a woman comfortable clothes that would flow with her body. A woman is closest to being naked when she is well-dressed.’(Coco Chanel, 1969)

Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or institution of learning.

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Abstract

Women aged 55+ are recognised to have non-standard body morphologies and may present with further functional considerations. Existing practice bases clothing development on younger bodies, exasperating misfit issues that exist already. This research therefore focuses on the assessment and provision of garment fit for mature women aged 55+. It applies and critically analyses the application of 3D bodyscanning technology and landmarking practice for the clothing product development process for mature women. Compared to traditional methods in anthropometric body measurement, 3D bodyscanning procedures have perceived benefits in speed, privacy and accuracy. It is therefore ideal in capturing the measurement of mature women aged 55+. However, bodyscanning may deal less well with non-standard bodies, which may complicate further pattern creation. Whilst bodyscanning has recognisable benefits (speed, convenience, consistency), the technology is not readily accessible to practitioners and necessitates its study and testing.

A pragmatic, mixed method approach was developed to gather and analyse qualitative and quantitative data related to body scanning and pattern applications. A theoretical framework was established from the knowledge base informing six propositions, a null and alternative of hypothesis. This research applied a mixed methods approach, allowing the exploration of the technology, the application of the data in pattern practice and the testing of its success with a suitable 55+ population. The research developed novel approaches to understand the data and ensure its validity.

Processes found that landmarking errors were not confined to 55+ demographic. Landmark errors concerning armscye, bust and crotch points were common; but the t-test revealed that older age was the variable most likely to impact on landmarking accuracy concerning bust and crotch points. Scan analysis added time to the scanning process which made the technology less time conserving as widely perceived. The study discovered that non-contact landmarking methods allowed errors that were not easily detectable without a reliable system in place; hence established a system for validation. Body measurements from the pattern guidance and body scan data measurements did not have comparable landmark definitions; therefore scanner landmark definitions needed to be modified for pattern construction, adding time to the process. Comparison of patterns constructed from unmodified and modified scan data revealed that landmark error had a substantial impact on key areas of pattern geometry. Changes in pattern shape translated into poor fit of the bodice, where armholes were either too tight/loose and the shoulder seam too short for the body. The bodice fit trials confirmed that participants favoured the fit of the bodice that had undergone landmark modification and had used their self-selected waist position.

Methods are necessary to ensure scan data is suitable for the application of pattern construction, this study provides clear approaches that allow this.

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1 Introduction and Background to the Study

1.1 Introduction to the thesis: the foundations of the research

1.1.1 Clothing industry experience and tacit knowledge as a motivator for the research

This research was conducted by a clothing practitioner with 18 years of clothing industry experience in garment fitting and pattern construction for a number of well-known UK high street retailers and for individual clients. Their work encompassed the construction of patterns and fitting of subsequent garments for woven and knitted garments from formal, casual and lingerie product categories for women aged approximately 18-80 years. During the course of developing garments for this mixed demographic it became apparent that women from the older end of the age spectrum (aged 55 and over) required more pattern engineering to accommodate changes their body morphology. For example the company insisted that jackets and coats always retained a small dart on the shoulder and a centre back seam, and skirts and trousers were designed with flexible waists. Despite these pattern adaptations customers from this demographic reported dissatisfaction with garment cut and fit.

Dialogue with these women either whilst they shopped in the retailer's stores revealed three factors that contributed to dissatisfaction with garment fit. Those three factors concerned age-related changes to their body, garment dimensions and garment styling. The women found an incongruence between their body morphology and that of the garments size and style lines. During the course of working in the clothing industry, the retailer, using a qualitative format (via dialogue or observations) from the customers, gathered data regarding clothing preference and fitting issues monthly. Using the feedback attempts were made to improve the clothing offer by revisiting size charts and grades as well as evaluating the garment attributes of particular garments, which sold well. Notwithstanding, the problem of poor fit for this demographic still remained perhaps because body measurements from the older demographic were not taken in store or online and size charts were based on one fit model's body dimensions and shape.

With the intention of researching the general issue of poor fit and its assessment by the clothing industry the author returned to academia in 2008 to undertake a Master's programme. A thesis was completed in 2009 as part of a Master of Science in Advanced Clothing Product Development. This thesis explored 8 clothing practitioner's practices and skill-set in terms of the garment product development process and garment fit assessment. This was done using 8 interviews and 8 observations of a fit session. The results revealed commonalities in skill sets between practitioners and found those who had worked for longer in the field were more expert at targeting and providing fit solutions. The majority of those interviewed were more concerned about garment dimensions and paid little attention to that of body dimensions, admitting that size charts are based on one fit model who was seldom measured.

Extracts from this thesis were published in 2010 at the Textile Institute Centenary Conference (the full paper can be read in Appendix B). The principle findings of this work were that clothing practitioners have varying skill sets, which improve with experience and that UK retailers, and manufacturers generally do not provide training to further develop the skills sets of clothing practitioners and instead rely on heuristic knowledge gained in previous employment (Wren, 2010). It also revealed that body measurements were not regarded as important, a surprising finding as clothing dimensions are first determined by that of the body. Such an approach suggested that the adoption of new and emerging technologies such as that of 3D bodyscanning systems for anthropometric data would be slow as current clothing practitioners do not see the need or have the required skill set to manipulate the systems for clothing development. This suggested a necessity to research the technology to make it more accessible and applicable for clothing practitioners to use in the course of their role. Consequently, it was decided that research around the usage and application of 3D bodyscanning technology for the clothing industry needed undertaking. This was because Wren and Gill's (2010) (Appendix B) work had confirmed that adoption of the technology by industry was slow and that some academically derived research were providing solutions to poor fit using tools and skill-sets that were extrinsic and inaccessible to those available to industry clothing practitioners and to students learning the discipline (Wren and Gill, 2010). Using the skill set gained from 18 years within the clothing industry this research focused on determining how the technology could be applied to improve garment fit for the older female demographic aged 55+.

With application in mind, the subsequent solutions from this research were developed for a clothing industry practitioner to comprehend and apply easily within their role.

It should be pointed out at this point that the term 'clothing practitioner' has been purposely used throughout this thesis. This is because the research was concerned with exploring how clothing fit could be improved for an older female demographic through investigation of the processes involving non-contact anthropometrics, landmark evaluation, pattern construction and fit assessment. The research therefore did not concern with itself with designing garments for an older demographic but rather providing accurate bespoke blocks from which a designer may adapt for new clothing styles.

The author has since worked as an academic for 7 years (from 2010 to 2017) teaching aspects of the product development process such as pattern development, CAD and garment fitting and amendment, and undertook this research during this time. It is during this time that this research has been undertaken, and it is this role that has taught the author that research though targeted at the clothing industry needs to be framed academically. Consequently in an effort to develop and present the research academically software/programmes such as TC^2's Image Twin, Gerber Pattern Design Systems, Excel and Visio were used/learned to help process, store and illustrate the research. In addition inferential statistical testing skills were also developed, as, although not a requirement for clothing product development, these were necessary to test the hypothesis and enable generalisation of the results.

1.2 Key literature which frames and gives purpose to this research

1.2.1 <u>Mature women and age-related body morphology changes</u>

Good fit is the principle factor in determining if mature women, (those aged 55+) will purchase a garment (2.10.2). Yet this demographic are most frustrated with the fit of ready-to-wear garments (Ashdown and O'Connell, 2006; Lee *et al,* 2012). Retailers that cater for older women often style their garments and base their pattern blocks on that of a younger, standardised, body shape and size (Hsu, 2009; Birtwistle and Tsim, 2005) as catering for a changed body morphology within the pattern and garment has the effect of ageing the garment (Twigg, 2014) something retailers wish to avoid.

An understanding and acknowledgment of the age-related changes in body size and shape and how this impacts on anthropometric practice and the anatomical landmarking process, by clothing practitioners (both in industry and academia) is fundamental to provide correctly fitting garments for women aged 55+. This is because as a woman advances towards older age and passes through the menopausal transition, she potentially loses height (Sorkin *et al*, 1999) due to altered posture owing to changes in her spinal architecture (Lindsey *et al,* 1980) and can gain excess fat deposition around the abdomen region of the torso (Wells *et al,* 2008). This increase in waist circumference gives rise to a more rectangular body shape (Goldsberry *et al,* 1996) as the waist is less discernible from the hips and bust (Lee *et al,* 2007). All of these age-related factors have the potential to alter body morphology away from what is considered by the clothing industry and anthropometric and pattern construction practice a standard size, shape and posture. For example, this change in body shape challenges generic landmark definitions such as that of the waist, which, if using observation alone, relies on a clearly discernible convex curve midway between the bottom of the rib cage and the top of the iliac crest.

1.2.2 Manual and non-contact anthropometric anatomical landmarking approaches

Manual anthropometric practice, both for anthropometric surveys and that provided in pattern construction literature, as illustrated in Appendix C, use a standard size, shape and posture on which to base its guidance. The standardised body is typically shown as having an upright posture and youthful body morphology, showing a clearly defined waist, a flat abdomen, a high bust point, and a clearly discernible crotch point as illustrated in the images within Appendix C.

Manual anthropometric practice involves two stages: anatomical landmarking and measurement reading and documenting. The practice requires observation and palpation of the skin surface terrain for particular muscle formations, points of prominence or bony protrusions which are then confirmed by the technician and possibly the participant as interaction is conceivable as technician and participant liaise with each other. Once found the landmarks and then marked in readiness for body measurements to be taken. This research's particular focus involved the landmarking stage of the anthropometric process for the 55+ demographic as errors in this stage can affect the accuracy of the measurement readings which are required to be correct to develop accurate patterns and well fitted garments.

The landmark and measurement definitions used by the 3D bodyscanner are benchmarked against manual anthropometric practice which uses definitions that are informed by ASTM or ISO standards (Shin and Istook, 2006; cordis.europa.eu, 2007). This means that 3D bodyscanning technology also uses a standard body size and shape to inform its landmarking process. Consequently, precision in the automatic detection and location of landmarks is particularly affected when applied to mature non-standard body morphologies, which are the result of the ageing process (Ashdown & Dunne, 2006; Ashdown *et al*, 2008; Ashdown & Na, 2008; Han *et al*, 2009). This is because 3D bodyscanning is limited by its reliance on surface geometry, without being informed by traditional palpation, therefore the level of precision when detecting and locating landmarks is dependent on a clearly written description, which will inform the programmed algorithm.

Landmark descriptions within the algorithms and the algorithms themselves within proprietary bodyscanning systems such as TC^2, Vitus and Cyberware are not made known to those outside of the company as they are part of the company's competitive advantage (Simmons & Istook, 2003). Accordingly, without this information, it is difficult to ascertain whether the software has accurately located the landmarks when using the 3D-bodyscanning for non-standard body morphologies unless a rigorous evaluation process is implemented by the technician undertaking the scanning (Appendix AI). Currently, no such rigorous process exists (Appendix AI) in the knowledge base which again provided the impetus for this research.

1.2.3 The clothing industries application of 3D bodyscanning technology

Three dimensional body scanning using non-contact landmarking and measurement practice appeared to be the favoured approach for the collection of anthropometric measurements as demonstrated in Appendix A). In recent years retailers, academics and government departments have various proprietary 3D bodyscanning systems for anthropometric surveys, such as SizeUK (Wells *et al*, 2007), SizeUSA (Loker *et al*, 2004) and Size Korea (Han *et al*, 2010). These surveys have collected population data concerning body size and shape which have been used for clothing related purposes. The technology is desirable as it accelerates the measurement process as well as preserving privacy for those participating (Fan *et al*, 2004). However, it is difficult to establish the accuracy of the measurements taken as details of each survey - in particular the process of scan viability and landmarking accuracy - is non-existent (Appendix A), and no reflective reports of the survey's process are published to show this has been undertaken (Bougourd and Treleaven, 2014). Indeed there is no current research which solicits ideas on landmark positioning evaluation and validation for any demographic let alone research specifically for mature women aged 55+ which gave this research its purpose.

Much of the research focused on improving non-contact landmarking accuracy originates from disciplines outside of clothing (2.8). Their methods and solutions require knowledge of computer science and advanced statistics - both of which are not normally required skills for clothing product development – which makes their methods difficult to apply within a clothing context. This gap in the knowledge prompted this research to seek ways in which it could improve landmarking placement using the skill-set already possessed from working 18 years within the clothing industry and from research and teaching the product development process as an academic for 7 years. This new process had to be accessible to the clothing practitioner enabling them to comprehend the process and manipulate it for their own roles requirements.

Three-dimensional bodyscanning technology's adoption by the clothing industry appeared slow with its main application being that of a survey tool (Aldrich, 2008). Although other uses of the technology have been explored for clothing purposes (2.11) knowledge of its application within the clothing product development process – the development of the pattern and assessment of garment fit - is currently limited (Gill, 2014b). This gave this research its impetus for exploring the accuracy of the technology (in terms of its landmarking) within the context of the pattern and garment.

1.2.4 Past anthropometric practice for a mature female demographic

Anthropometric surveys specifically for a mature (over age 55) female demographic that have used traditional measurement practice (2.2) have encountered problems associated with modesty because of the methods and equipment used (2.5.1). They found this demographic could be sensitive about being measured in a state of semi-undress (3.4.1) and were more open to participation if they could be assured of confidentiality, both during and after the anthropometric process (3.5.1). These past surveys (2.5) have had to develop particular protocols or tools to enable the technician to take and read correct body dimensions from participants with non-standard body morphologies whilst maintaining a level of privacy for the participant.

Both Gill *et al* (2014a) and Haffenden's (2009) research acknowledged that new protocols need to be generated, when devising a anthropometric approach (both manual and non-contact) for women who do not have a clearly defined waist or have a non-standard body morphology. Both studies state that this could be possible using proprioception, the participant's knowledge of their bodies, and how they wish garments to fit (2.3.5).

1.2.5 Mature women's requirement of garments

The literature confirmed that mature women are knowledgeable about their body (Haffenden, 2009), understand how to use clothing as a means of presenting the body in an aesthetically pleasing way (Grogan *et al,* 2013; Richards, 1980) and are well-informed regarding clothing fit (Zhang *et al,* 2002; Newcomb and Istook, 2004). This indicated that they are well placed to offer input into the development of their garments, both in terms of where they would like their body measurements to be taken (informing the position of the landmarks) from for pattern construction and as feedback on how the garment attributes conform to their body morphology. Yet no current research has attempted to devise a system for mature women that allows their interaction during both the pre and post bodyscanning process. This again suggested, as with the scan evaluation and validation, a need for greater consideration of this area, which this research set out to do within this thesis.

1.3 The Aim of the research

This thesis Aim was threefold:

- The first part of the Aim was to explore determine if the 3D bodyscanner was accurate in its landmarking and subsequent body surface measurements for women aged 55+ using the skills sets already possessed from 18 years' worth of industry experience. Therefore, a set of hypothesis were developed as detailed in section 3.6 and from this, the null hypothesis was tested using a t-test. However testing a hypothesis using descriptive and then inferential statistical calculation such as a t-test (as this thesis did) will only provide information concerning the probability of the null hypothesis being either true or false. It does not examine possible cause nor offer a solution to the issue of poor fit.

- Therefore, the second part of the Aim was to develop a tool, in the form of a questionnaire and the visual aid, which utilised participant proprioceptive knowledge of their body to engage them more fully within the 3D scanning process in order to improve body surface landmarking, and subsequent body measuring accuracy for pattern/toile development. This information also prompted the development of a fit pro forma (Appendix Y) which would facilitate evaluation of the toile to demonstrate if fit has improved.

- The third part of the Aim was to create a process/tool which established why errors in scan image or landmark positioning can occur for these women as well as offering the opportunity to modify difficult to locate landmarks (like the waist) to a more appropriate position based on the feedback for the visual aid from the participant.

1.3.1 The five Objectives to achieve the overall Aim of the study

1. Establish knowledge gaps in the areas of automatic anthropometric landmarking through comparative analysis of body measurements and body measurement technologies found within the knowledge base. The data for this objective was gathered using a survey methodology to collect two sets of data. The first set of data comprised of 3D bodyscanning hard and software information and the second set comprised of landmarking methods which was extracted from scanner brands marketing materials and academic articles which have devised processes for its usage by the clothing industry (see *Figure 3-1*, *Table 3-2*: Activities 8, 9 and 10).

   The deliverable from Objective [1]:
   Determined if the technology required special skill sets or knowledge to enable its implementation and application by the clothing industry. It also began to

determine strong and weak relationships within the Landmarking Methods table survey which contributed to the creation of the conceptual model in Objective [2].

2. Assemble and identify relationships between manual and automatic methods of measurement using the information provided by the Landmarking Methods table and secondary data of previous anthropometric surveys within the table of Anthropometric Surveys for Objective [2] (*Figure 3-1, Table 3-2:* Activities 8, 11 and 12). Specific details of each survey were tabulated for comparative analysis. The resulting analysis was presented as a conceptual model.

   The deliverable of Objective [2]:
   The assemblage of the three different approaches to human body measurement and the relationships between each of them in the form of a conceptual model.

3. Evaluate the effectiveness of non-contact landmarking against the mature woman's body surface dimensions and body shape using comparative analysis of a younger female sample. Objective [3] utilised an anthropometric survey of a mixture demographic of women to collect both quantitative and qualitative data using 3D bodyscanning technology, a questionnaire and a visual aid (*Figure 3-1*,*Table 3-2*: Activities 8, 13, 14, 15, 16, 17, 18, 19 and 20).

   The deliverable of Objective [3] was twofold:
   First provided generalised results concerning landmarking accuracy for a 55+ female demographic. Second engaged the participant in the 3D bodyscanning process and developed new process called the CDVELA was developed to explore possible cause of landmark error for these women. The CDVELA process also facilitated landmark amendment based on participant feedback.

4. Establish industry requirements of 3D bodyscanning technology via a survey of UK retailer provided body measurement guidance and a case study of a large High street retailer and manufacturer to determine how anatomical landmarking is

used within their organisation (*Figure 3-1*, *Table 3-2*: Activities 21, 22, 23, 24, 25 and 26).

The deliverable of Objective [4]:
Established the quality and appropriateness of retailers' measurement guidance for a mature female demographic. Provided new insights into how a large UK High street clothing retailer perceives and utilises 3D bodyscanning technology within its business. This Objective also provided an opportunity to validate the new CDVELA process using the data from the retailer's non-contact anthropometric survey.

5. Develop a process and accompanying tools using the theoretical framework which integrates pattern construction with participant confirmed landmark definitions and measurement protocols to realise improved garment fit. Patterns and toiles were developed using unmodified and modified scan data. The toiles were fitted and participant feedback was gathered using a specially developed fit pro forma (*Figure 3-1*, *Table 3-2*: Activities 27, 28, 29, 30 and 31).

   The deliverable from Objective [5]:
   Contributed new knowledge within the areas of non-contact anthropometric landmarking amendment and validation especially for clothing, pattern development protocols for mature women's bodice blocks and participant provided fit assessment using a new fit pro forma document. All tools and processes were developed by this thesis to be accessible to both current clothing practitioners and new entrants to the clothing industry which is novel.

1.4 The structure of the thesis

The structure of this thesis has been developed to logically present the gaps in the current knowledge base. These gaps relate to female age-related body morphology changes, non-contact anthropometric practice and participant proprioceptive knowledge, bodyscanner data evaluation, validation, landmark error diagnosis within the context of bespoke pattern development and garment fit testing sessions, and the development of an appropriate methodology and findings with accompanying discussion of the research. Each chapter supports the development or presentation of the findings.

Chapter one is the ‘Introduction and background to the research’. This chapter contains the major areas for consideration using key references. This research identified that mature females (those aged 55+) can experience age-related body morphology changes which take their body morphology away from what is considered standard by the clothing industry and by anthropometric practice. These body changes are not accommodated within generic anthropometric landmark and measurement definitions used in either manual or non-contact measurement approaches. Age-related body morphology changes are also not accommodated for within pattern construction guidance as anything that does not conform to what is considered standard is seen as erroneous and requiring a pattern fit correction. Moreover scan and pattern measurement definitions differ making pattern development using specific guidance challenging using bodyscanner measurement data. Currently no method of scan data evaluation and valuation for clothing practitioners exists in the public domain and in the absence of this; it is difficult to ascertain scan data accuracy for women aged 55+. With these gaps in the knowledge outlined the research investigated the following areas of:

- Female age-related morphological change
- Traditional and non-contact anthropometric practice for clothing development
- Pattern construction and fit amendment guidance
- Proprioception and self-assessment for anthropometric measurement
- Three Dimensional bodyscanning application and limitations

Chapter two is the ‘Literature review’ which frames the research. Each of the above areas charted the research development and knowledge gaps and outlined the progression of knowledge which supported this research. The order in which each area is discussed generally follows the order bulleted directly above this paragraph.

Chapter three covered the ‘Methodology to establish the viability of 3D bodyscanning as a tool to improve garment fit within the clothing product development process for mature women aged 55+’ whose whole process is shown in *Figure 3-1* and whose purpose and activities are detailed in *Table 3-2*. This chapter detailed the philosophical viewpoint –

which is pragmatism - taken and adopted by this research, by providing a rationale of how and why methods were developed and applied. In accordance with the pragmatic viewpoint, both qualitative and quantitative methods were developed to collect and analyse both kinds of data. Existing methods and their limitations were discussed thereby providing a rationale for the generation of new methods as appropriate for this research.

Chapter four contains the 'Findings and discussion – part one' and encompasses the findings and discussion of the Research Objectives [1], [2], [3] and [5]. The structure is such that the each finding was presented then was initially followed by discussion, which compared the finding to established knowledge. This section chapter began with the analysis of the qualitative secondary data to build a greater understanding of the 3D bodyscanning technologies process, and, how it compared to traditional anthropometric practice. The findings from Objectives [1] and [2] were presented in a graphic format (a model) which is broken up into organised stages. Following this, the qualitative results of this research's scan questionnaire and visual aid for Objective [3] were presented in a number of ways. Tables, models, charts and direct quotes were used to present these qualitative findings as it was determined that this was the most direct and economical way of presenting the results. Objective [3] also utilised comparative scan data (from a mixed demographic) which was mainly quantitative in nature and this determined that the findings be presented as descriptive statistics in chart form with images and discussion to demonstrate a particular point or observation. Objective [5] within this chapter contained qualitative findings in the form of observations of the pattern drafting and garment fit processes. Graphics of the pattern and images of the participants in the toiles and tabulation of the fit pro-forma responses were used to present the findings and support various points of discussion. Each finding was related to its Objective, which demonstrated the accomplishment of said Objective. Correspondingly, Chapter four demonstrated the completion of the overall Aim which was outlined in section 1.3 above.

Chapter five covered the 'Findings and discussion – part two'. This chapter contained the findings and discussion of Objective [4], which was the retailer measurement guidance survey and the case study. It addressed the theories and knowledge gaps identified within the theoretic framework shown in the closing statements of the literature review. Content analysis using open coding of the qualitative data (the written and visual content) from the measurement guidance survey was reduced and analysed using a tabular format and the subsequent findings were presented as images, tables and text. The findings of the case study were also qualitative and presented in a written format which were supported by quotes and images within the Appendices which drew on the themes identified by this research.

Chapter six was the conclusion to the research. This chapter placed this research's contribution of new knowledge within the context of the current knowledge base and discusses how it could be used to further support clothing practitioners who operate within the process and the clothing product development process itself. Limitations and recommendations were included that outlined how the research could be further developed.

2 Literature Review

2.1 Introduction to the literature

This thesis seeks to apply and evaluate 3D bodyscanning technology and landmarking practice within the clothing product development process to improve garment fit for mature women aged 55+, as issues with garment fit for this demographic were already known via the tacit knowledge of and practical experiences of the author (1.1).

With consideration of this, the work commenced with this chapter, which is a review of the literature base to establish the key themes and theories and to identify the knowledge gaps. Therefore, this chapter examines the current literature surrounding the themes and accompanying theories of:

- Generic anthropometric practice
- Female age-related morphological change,
- Body measurement guidance and clothing pattern development
- Anthropometric studies for mature women,
- Anthropometric surveys using 3D bodyscanning technology,
- Non-contact landmarking methods
- Mature women's perceptions of 3D bodyscanning technology
- Mature women's understanding and requirements of clothing,
- Clothing retailers' view of female ageing and their clothing offer
- Current applications of 3D bodyscanning technology by the clothing industry.

The above themes and accompanying theories were synthesised and critically reviewed within this chapter to form a theoretical framework (2.12). This framework suggested that the areas of generic anthropometrics, pattern development guidance, non-contact anthropometric practice and systems and clothing retailers are either not catering for or are unaware of the age-related changes that a female body undergoes, and as a result were unsuitable for this demographic.

The other themes and theories of mature women's perceptions of 3D bodyscanning, their understanding and requirements of their body size, shape and clothing needs provides indications that a workable solution to improving clothing fit whilst applying 3D bodyscanning technology within the clothing industry practices is possible details of which will be discussed within the methodology chapter.

2.2 Anthropometric guidance and the mature female's body morphology

2.2.1 <u>The practice and purpose of anthropometric measurement for clothing development.</u>

Anthropometry is the practice of preparing and measuring the human body surface (Croney, 1980, Beazley, 1997). Clothing practitioners have a continuing need for current anthropometric data from which to base their garment dimensions (Croney, 1980), as human body dimensions are the precursor to garment pattern and size chart development (Beazley and Bond, 2003, Beazley, 1997).

There are two distinct applications of anthropometric practice, one that uses a static posture (as in *Figure 2-1*), which according to Croney (1980) and Bunka (2009), is utilised for garment development and the other using dynamic posture (as in *Figure 2-1*) which again, according to Croney (1980) is more appropriate for ergonomic design. This research focuses on anthropometric practice for clothing design and, therefore, discusses anthropometric practice using a static posture.

Figure 2-1 Dynamic and static posture Source: Posturologyblog.com, (2015)

Many of the publications centred on anthropometric practice and direction – for example, Lohman, (1988), O'Brien and Shelton, (1941); Croney, (1980) and Beazley, (1997) are generated as a guide for individuals wishing to undertake manual measurement for discipline specific application. These guides provide details regarding the stages involved anthropometric practice and confirm that the practice involves two stages, which are preparation and recording. They also state that the technician taking the measurements needs a good working knowledge and experience of the human figure as well as the ability to make the participant feel at ease by building a good rapport with them.

This knowledge and experience is necessary, as the preparation phase of the manual measurement requires that the participant is prepared by marking landmark points, as can be seen in Kunick's pattern construction guidance (11.1.12), on their body (Magnenat-Thalmann & Thalmann, 2004; Beazley, 1997; Croney, 1980). These were areas associated with the underlying skeletal structure or soft tissue regions that displayed specific contour configurations (Kunick, 1984; Appendix C: 186) as beginning and end points or to indicate the depths/levels between circumference measurements (Beazley, 1997). Gill's (2009) earlier work exploring landmark categorisation and definition found that landmarks were actually more varied in how they can be classified. Gill (2009) consults the work of Basmajian (1983); Field (2001); Byfield and Kinsinger (2002) – all of which act to some extent as guides to landmarking practice - and concludes that to afford sufficient understanding into landmarks required the consultation of a variety of sources, although the varied terminology could be a barrier to quick comprehension.

Familiarity with different landmark terms and a variety of surface anatomies is the key to successful landmark placement, as a practitioner must understand what to observe and palpate for when demarcating the landmarks. In addition, as they are required to touch the participant's body and see them in a state of semi-undress they must also help the participant feel at ease.

The recording phase requires the technician to use specialist measurement equipment to read skin surface measurements that are then documented for later use (Croney, 1980; Beazley, 1997) in pattern development, size chart generation or the calculation of suitable grade rules.

Despite the proffered guidance, Beazley (1997) states that measuring the human body manually is difficult as much is left to the judgment of the technician, particularly with respect to the preparation stage and, more specifically, the location and demarcation of landmarks. The thinking is the greater the experience and skill of the technician the better the accuracy in traditional manual body measurement.

Lohman *et al*, (1988); O'Brien and Shelton, (1941); Kunick, (1984); and Beazley's (1997) publications all provide anthropometric landmarking definitions and measurement recording guidance based on a figure that displays a standard upright posture, has little or no excess fat deposition and which appears youthful. The use of these idealised bodies in landmark guidance, does not accurately reflect an older female demographics' body morphology or take into account considerations of their landmarking and body measurement. In addition these guides are written within the context of their own survey process and often contain information, which is inaccessible to persons new to anthropometric practice. For example, Beazley's (1998) guide is a two part academic publication that discusses how to undertake a small anthropometric survey of young women to collect data for size chart generation. Likewise, Kunick's (1984) textbook guidance is informed by its own practice for size chart and garment pattern development. Lohman *et al's* (1988) textbook provides guidance on standardised measurement techniques, which, apart from discussion on measurement variance dependant on the left or right side of the body, has no explicit guidance for measuring an ageing demographic. O'Brien and Shelton's (1940) guidance is informed by their own survey practice where they measured 14,689 participants for size chart development and whose ages were predominantly between 19-30. Therefore, information on measuring women aged 55+ years females is extremely scant. Therefore in conclusion, all of the guidance mentioned above provides enough information for those already familiar with anthropometric practice to measure a younger demographic whose body morphology could be termed as standard.

Croney (1980) – whose work (in the form of a textbook) aims to educate those new to anthropometric practice and Schewe (1988) – whose academic paper mainly focused on marketing to an ageing population - determined that the gradual degeneration that occurred to the human body through ageing varies greatly between individuals and can affect body size, shape and posture. Schewe's work will be discussed later in this thesis (2.10.3) when the discussion turns to retailers' ideas of mature women's body shape and proportions. Returning to the work of Croney (1980), when discussing anthropometric guidance it is important to mention that Croney's (1980) publication is the only work of its kind which discusses anthropometrics and the ageing body, which this thesis finds significant as everyone ages. With that in mind however, what is missing from Croney's (1980) work is any anthropometric guidance specifically for a mature female demographic. Details of the physical body size/shape changes for an ageing demographic are described within the publication, showing recognition of their importance, but the omission of guidance leaves a practitioner the need to develop skills in navigating them through practice. Consequently, in summary Croney's (1980) publication provides more concentrated information, than any of the aforementioned works, on child-to-adult growth and morphological change, with information and schematics on adult-to-senescent (biological ageing or the state of being old or the process of becoming old as defined by Merriam Webster, 2016) morphological change being less explicated. Discussion of elderly body changes are not in explicit detail and the schematics he provides lack the same level of analysis evident in the growth to maturity images. This omission highlighted a lack of clear details from which to develop and tailor specific guidance for mature female demographic. Therefore, using Croney's (1980) guidance to landmark and measure an older female participant would prove challenging for those with no experience of age-related body morphological change.

As body-surface measurement, data is necessary for the development of garment patterns that accurately fit the body (Bye *et al*, 2006; Gill 2015; Chun, 2007). It could therefore be argued that a greater understanding of body surface changes due to ageing is necessary to enable practitioners to accurately extract the right measurements from the right areas of the body for subjects who no longer display a standard body size and shape as evidenced in Appendix C.

Watkin's (2011) discussion - which involves design, pattern development and fit within the clothing industry - asserts that traditional garment fit is determined by the interpretation of what clothing practitioners perceive to be an ideal body shape and size, of which their chosen fit model represents. It has also been suggested by studies surrounding the development of new sizing standards for mature women (Hsu, 2011) and studies which explore mature women's satisfaction with the fit of High Street clothing (Birtwistle & Tsim, 2005) that garments targeted at a mature demographic are cut to fit a younger body shape. This suggests that either retailer's fit models are not truly representative of their consumer or that they do not recognise that as women grow older there will be changes in body posture and dimension as a result of ageing.

Many or all of these physical changes due to ageing affect garment fit and comfort levels as the body moves gradually away from what is recognised by the clothing industry as an ideal/standard body size, shape and posture.

2.3 The effects of aging on a mature women's body

Anthropometric measurement practice involves three phases. These are how the landmarks are located and positioned/demarcated; how measurements are extracted; and the manageability of posture adoption for certain anthropometric measurements. Recognition and understanding of adult-to-senescent morphological change is vital as these physical body changes can affect these three phases of anthropometric measurement.

2.3.1 <u>Height loss, change in posture and bilateral asymmetry</u>

The reduction in overall height through ageing is well documented and cited as important by Croney (1980) and Sorkin *et al* (1999) when considering measurement of the body. Sorkin *et al*'s (1999) longitudinal study of height change in both men and women found that height loss is greater in women than men, with height loss accelerating with increasing age. It should be noted that Sorkin *et al* (1999) only observe height change and do not expand as to why height change occurs which is a limitation of their work. Notwithstanding, Lindsey *et al*'s (1980) nine-year study of the effects of hormone replacement therapy on 100 menopausal women provides the link with height loss and reduced hormone levels due to the onset of the menopause. Their study found that subjects who had lower levels of bone density (*Figure 2-4*) displayed a significant reduction in height. Lindsey *et al's* (1980) discussion of the findings state an occurrence of lower central vertebral height (segments of the spine), and larger wedge-angle on the spine segments explain this height loss (*Figure 2-3*). Lindsey *et al* (1980) confirm that this reshaping of the individual vertebra is a result of small fractures of the spinal segments

(*Figure 2-2*) which is due to lower mineral levels in the bones making the bone matter less dense and more prone to splits or fissures. The reduction in mineral bone density (*Figure 2-4*) gives rise to a health condition termed osteoporosis (Christodoulou and Cooper, 2003). Reduction in bone density for women has been attributed to lowering hormone levels because of the menopause transition which, according to a study of factors which affect the onset of menopause by Gold *et al* (2001) is estimated to occur at approximately 51 years of age. These studies, when combined, afford understanding as to the reasons why height loss is more prevalent in women than men, as it is directly related to that of the menopause. It also reveals why many studies (from different disciplines including anthropometric measurement) focussing on a mature female demographic have age 55 as a starting point as this is perhaps when the first changes in height become more visually apparent. Finkelstein *et al's* (2008) longitudinal survey of 3302 women from different ethnicities between the ages of 42-52 found bone mineral loss occurred at different rates for different women. This concurs with Croney's (1980) work, which states that postural change is gradual, and varies from person to person. Finkelstein *et al*'s (2008) focus was the lumbar spine and hip bone region, perhaps because it is these two regions along with the wrist joint that are most at risk of fractures (Christodoulou & Cooper, 2003). Therefore, it should be noted that any fracture of the spine could alter vertebral height and could produce larger wedge-angles on the spine segments (*Figure 2-3*). This, in turn, has the ability to change overall posture and skin surface topography making landmarks such as the nape of the neck/7th cervical visually less apparent. This, of course, has implications for non-contact landmark location (found within 3D bodyscanning practice) methods and demarcation for individuals with curved spine.

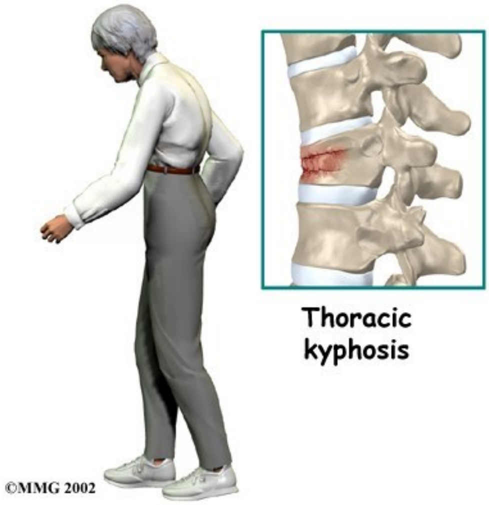


Figure 2-2 Bone fissures in the spine source: Houstonmethodist.org (2002)

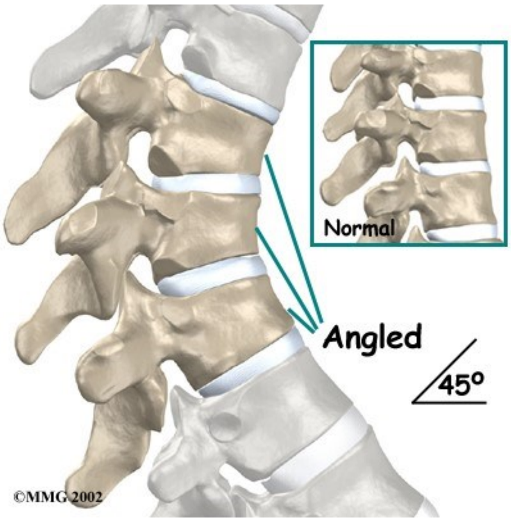


Figure 2-3 Wedge angle of the spine source: Earthpod (2002)

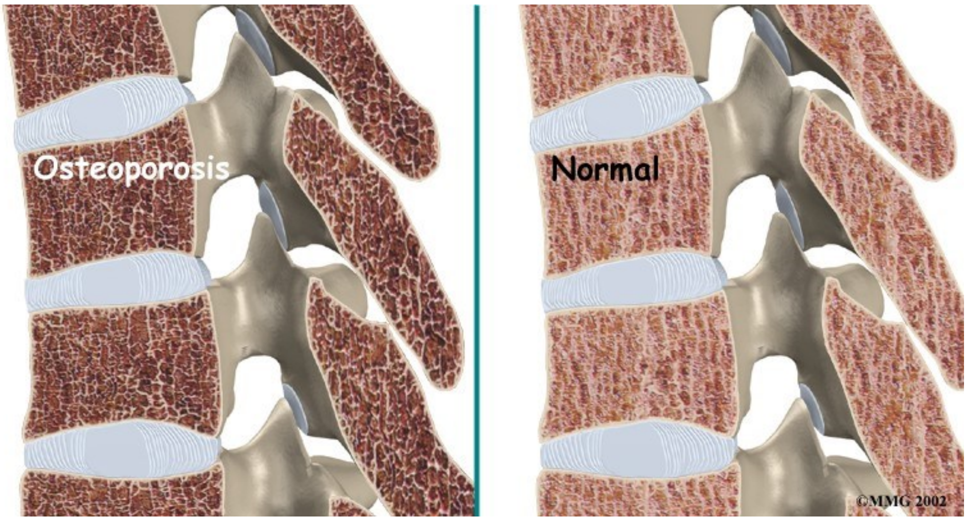


Figure 2-4 Bone density for a normal bone and one which has osteoporosis source Houstonmethodist.org (2002)

Cutler *et al*'s (1993) early study examine the prevalence of kyphosis in a healthy sample of pre and post-menopausal women, maintained it is this wedge-angle structure of the individual vertebrae (Appendix E, *Figure 2-3*), the osteoporotic condition, which changed the architecture of the spine shape and gave rise to a kyphotic posture also termed kyphosis of the spine (*Figure 2-5*).

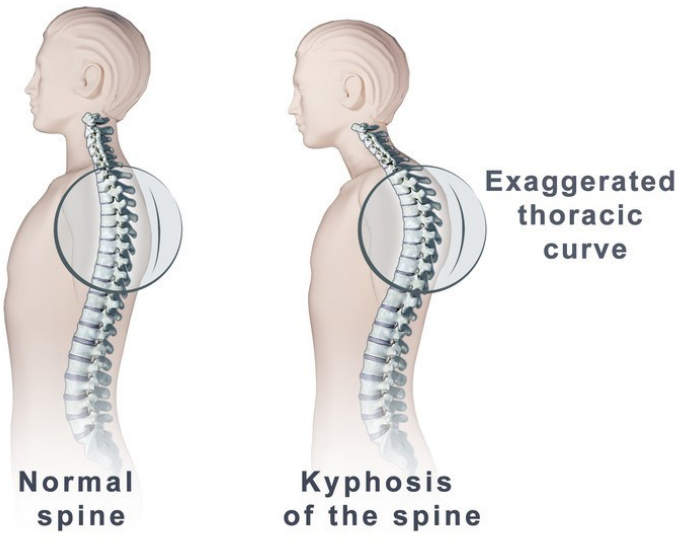


Figure 2-5 Normal and kyphotic posture source: Knowhow.MD (2016)

Cutler *et al* (1993) describe this curvature of the spine as the back appearing more hunched (*Figure 2-5*) and the shoulders rounded and curved towards the front, a condition Woodson and Horridge (1997) encountered within their anthropometric survey and found impacted on their measurement methods. Cutler *et al* (1993) alternatively term the condition 'Dowagers Hump'. This condition is also described as an arthritic condition of the spine predominantly in women, according to BS 4467 (BSI, 1991) a standard developed to provide information primarily for ergonomic design but which offers insight into characteristics of ageing. Cutler *et al* (1993) state that kyphotic posture advances whereby an individual can no longer straighten the vertebral column and remain fully erect. In addition, their head hangs more forward and not in the Frankfort plane (*Figure 2-6*).

Figure 2-6 The Frankfort Plane Source: Scottish Health Survey (2008)

In addition to changing head position, the process of ageing can give raise to bilateral asymmetry making one side of the body, the shoulders for example, appear different in terms of their angles (Ashdown and Na, 2008). Bilateral asymmetry effects balance in an older person, which in turn makes posture less stable (Blaszczczyk and Michalski, 2006) which can affect the recording of anthropometric measurements both manual and non-contact. This is important as literature concerning clothing measurement guidance require that in order to extract accurate full stature/height or segment length measurements of the body, the adult participant's posture has to be stable and erect, even when standing or seated (Kunick, 1984; Beazley, 1997; Bunka, 2008; O'Brien and Shelton, 1941, Lohman *et al*, 1988). This is due to the manual equipment used, the anthropometer, where length and height measurements originate directly from the floor, rather than the surface of the body.

Mature women who have undergone a level of spinal shape change or whose bodies manifest a level of bilateral asymmetry may find difficulties in adopting a straight and stable upright posture, which can be a sensitive issue for them. This, in turn, makes it challenging to use the anthropometer to achieve full vertical length measurements. Therefore, it is unclear if height measurements for participants displaying extreme levels of kyphosis are genuinely accurate as the measurement is read from a rigid structure and not taken along the skin surface.

This inability to retain an upright posture has implications for modern anthropometric 3D-bodyscanning, as accurate scan capture and measurement extraction relies on maintaining a standard upright posture (McKinnon & Istook, 2002, Sims *et al*, 2011). This change in posture increases surface lengths, both front and back, which do affect garment lines and balance. Therefore, consideration of postural change at an earlier stage than post pattern construction – as is the case with current methods - is beneficial.

With regard to automated non-contact anthropometric measurement practice, Brunsman *et al's* (1997) early study of optimum body posture and positioning for body scanning practice determine three standard positions to obtain accurate body surface image capture and ensuing body measurement. The three postures consists of two sitting down and one standing – all of which are useful for clothing development. The work is limited in that its recommendations are developed only for 3D bodyscanning technologies that allowed posture variation whereas not all 3D bodyscanners brands/models can facilitate this, the TC² being one example that cannot. The TC² bodyscanner can only effectively extract skin surface dimensions from a person who is standing, facing forward, arms slightly away from the sides, and feet slightly apart with the face looking straight ahead in the Frankfort plane (Appendix O).

Smrcka (2015) used crash test dummies to trial out each of the three postures within a 3D bodyscanner instead of human participants. Crash test dummies are developed to test protective systems and although they are made to simulate human size, weight and age they cannot effectively mimic the subtle changes and variations in posture displayed particularly by an aging person. Sims *et al*'s (2011) comparative study of non-contact (the TC² bodyscanner) and manual anthropometric practice for older and physically impaired participants facilitated some understanding of how a changed body morphology – and more specifically postural change - could influence the accuracy of landmarking and the delivery of accurate body dimensions. Their sample frame consisted of 103 people (aged 18 – 59) which included both genders and participants who were either mobile or had mobility issues. The study, though not undertaken for clothing development purposes, highlights that traditional methods can account for postural change whereas non-contact could not. They explained that this was because the TC² technology relied on the use of a body model template (details of what a body model template is and how it is used are discussed in section 2.8) in its software and individuals, whose body did not match the predetermined template could not be provided with complete body measurements. This use of templates highlighted a limitation, with potentially varied and non-standard bodies not being dealt with appropriately within a bodyscanning system.

2.3.2 Posture quantification of 3D-bodyscanning technology

Ashdown and Na's (2008) paper both identifies and quantifies upper postural body variation in both young (19-35) and mature (55+) female subjects using 3D-bodyscanning technology.

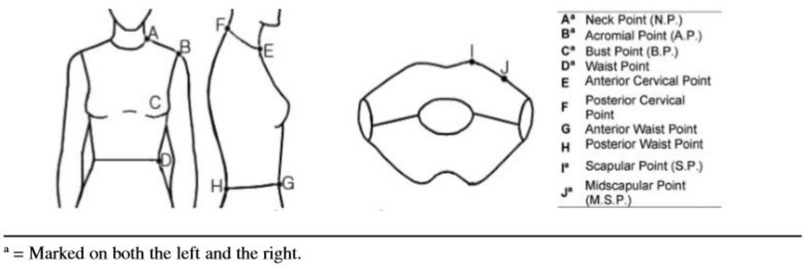


Figure 2-7 The landmark definitions used by Ashdown and Na (2008) Source Ashdown and Na (2008)

Their method required the use of Polyworks (a third party software used alongside the 3D bodyscanner) to enable the extraction of body angle measurements from the skin surface.

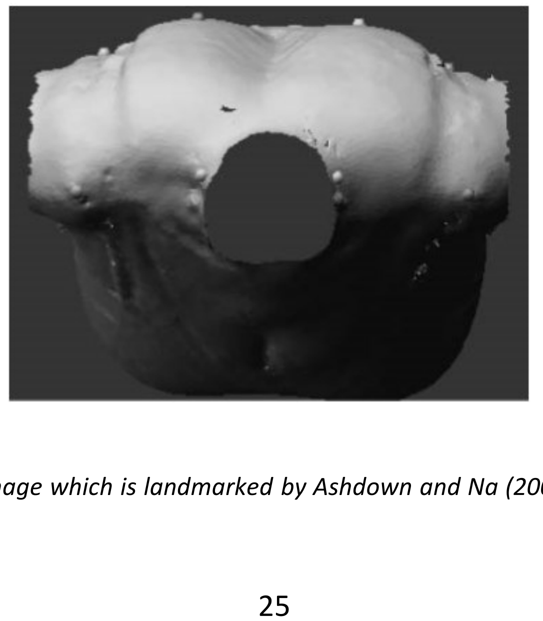


Figure 2-8 The Polyworks image which is landmarked by Ashdown and Na (2008) source: Ashdown and Na (2008)

Their analysis is was concentrated to the upper torso region of the body, a part of the body known to change due to ageing. Their study is important as it demonstrates significant measurement angle differences between both sample sets, highlights body posture change, and provides a new method of measurement extraction. The limitations of the study however are their sample sets originated from previous research studies resulting in Ashdown and Na (2008) having limited control regarding the sampling rationale and methodology. They were unable to assess the subject's body topography - defined as skin surface configuration (Dictionary.com, 2011) - and instead had to work with scans of individuals who had been required to wear a Lycra bodysuit, which obscured parts of the torso and hid subtle details along the skin surface required for landmark location. This perhaps explains why there is a lack of clear visuals of both the younger and older samples within the academic paper. The landmark definitions used by them were scant in their detail (*Figure 2-7*). The scans were only visually assessed and virtual landmark markers were placed where they thought they should have been (*Figure 2-8*). Indeed, Ashdown and Na (2008) conceded in the discussion portion of their work that locating virtual landmarks on the mature sample was difficult as the body changes affected areas where the landmarks are located on a younger person. Therefore, current literature confirms that height lost via postural changes is one morphological change that can be linked to the ageing process, which affects all three phases; namely, landmark identification and positioning; and manageability of posture adoption for certain measurements.

2.3.3 Weight gain and torso shape change

Hughes *et al's* (2002) longitudinal study of changes in body composition in both men and women conclude that fat mass increases in both men and women as they age but that this is more accentuated in women of advancing age. It could be confirmed, therefore, that, dependant on age, women may carry more subcutaneous fat than men. Where this fat is distributed is important as fat deposits can obscure some landmark locations on the body. Chumlea *et al's,* (1984) early study of subcutaneous fat in older adults (aged 54-85) found that older women have less adipose fat thickness on the arms and legs and more on the torso region of the body. They propose that this could be due to muscle loss because of ageing.

Schofield *et al's* (2006) investigation into pants fit for mature females found that this demographic tended to have flatter buttocks than that of a younger female demographic, which has implications for the fit of trousers. Shimokata *et al* (1989) used manual anthropometric practice for their investigation of body fat distribution in both male and female participants' age between 17-96 years. A sample of 408 women were measured over a period of 7 years using a tape measure for circumferential measurements and a callipers to measure skin-fold thicknesses. Waist, hip thigh and arm circumferences were taken alongside subscapular (the fat area around the shoulder blades) and triceps (the back of the top portion of the arm) skin fold thicknesses and these were calculated into ratios and percentages, which were then compared for the different age groups. Interestingly, the team reported difficulties in finding a suitable waist position for obese participants by visual analysis alone and, therefore, as they were using manual methods the technician was able to find a mid-region between the lowest rib top of the iliac crest via physical contact with the participant. The results indicated that the waist circumference increased in women between the ages of 40-70. Additionally, Shimokata *et al's* (1089) work also found that subscapular and triceps thicknesses and arm circumference also increase for women between the ages of 30-70. Moreover, they found that hip and thigh circumference did not rise or fall and were stable across the ages.

Ley *et al's* (1992) later work sought to determine fat distribution in both young and mature females' bodies using a different approach. Their work examined sex and menopause related changes in body composition and regional fat distribution in a sample set of 131 women aged 19 -63. Using x-ray technology (a CT scanner) to measure body fat they identified differences in fat distribution in women that were pre and post-menopausal. Post-menopausal subjects, (some of the sample aged between 43 and 63 years of age) had a higher body mass index than the premenopausal participants and the distribution of fat tended to be concentrated at the lower torso and thigh region of the body. This finding concurs with previous studies whereby mature females had larger waist and abdominal arcs (Patterson & Warden, 1983; Schewe, 1988; Woodson & Horridge, 1990; Goldsberry *et al* 1996; Salusso *et al*, 2006).

A study of Korean women's body shapes by Lee and Nah (2008) found change occurs in the torso region of the body whereby bust, waist and hip girths showed greater values when compared to women in their 20's and 30's. Their study – which primarily focused on the waist - illustrates where the site of changes occurs. They accomplished this by producing a range of models showing a thickening of the waist region and an increasingly extended abdomen, however, the models did not show the increase in spinal curvature or forward set of the shoulder angle that would have been a truer representation of body shape change in older women.

Goldsberry *et al's* (1996) study attempts to categorise the body shapes of the females they measured, and found the rectangle shape to be the most prevalent. This finding is further supported by Buffa *et al's* (2005) later study of variations in Somatotype of elderly males and females based in Sardinia, Italy. Somatotyping – developed by William Sheldon in 1940 - described the physical characteristics of the body and allowed definition of particular body types based on the analysis of their measurements (Somatotyping.org, 2016). Buffa *et al's* (2005) study sampled 280 males and females aged 60-89 years. They found, using a manual anthropometric survey, that the females displayed a dominance of endomorphic (heavier and fatter) or mesomorphic (larger musculoskeletal frame). This was due to changes in both lean and fat tissues where the quantity of fat mass increases until age 60-75 and after that the trend can invert. They also found that sexual dimorphism (the difference in body shape between men and women), with regard to waist shape, decreases with age where women's body shape change in the waist region was such that is was less distinct from a male's. This implied that some women lose their waist curves, something that is linked to the menopausal transition (Ley *et al,* 1992), and would account for a rectangular torso shape (Goldsberry *et al*, 1996).

In a similar vein to Buffa *et al's* (2005) work, Wells *et al's* (2008) investigated age associated body shape changes and related specific quantitative body mass index (BMI) bands and selected girth measurements using secondary scan data taken from the Size UK survey. In descriptive terms, the BMI bands they used were categorised as 'thin', 'normal weight', 'overweight' and 'obese'. Their study drew on scan data collected via the TC^2 scanner for the SizeUK survey, which was launched to determine the UK population's average body sizes, shapes and shopping preferences. The survey was undertaken as a collaborate effort between the department of trade and industry, a consortium of UK clothing retailers and eight UK universities. Although the main purpose for the Wells *et* *al's* (2008) research was epidemiological. The survey's purpose was to provide anthropometric data for clothing purposes, the findings of Well *et al's* (2008) work were able to use this data to show that both young and more mature females who displayed the same BMI bands were different body shapes dependant on their age. With younger obese females displaying an hourglass shape and mature females displaying higher android fat (the distribution of excess fat, predominantly around the abdomen and trunk, and within the abdominal cavity as defined by Wells et al, 2008) around the abdomen and manifesting a rectangle torso shape thereby having less definition in the waist region as seen in *Figure 2-9* on the next page.

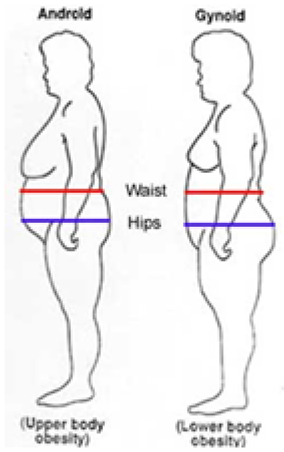


Figure 2-9 Android and Gynoid Fat distribution Source: Indiana Univeristy.edu (2011)

Perissinotto *et al's* (2002) earlier manual measurement survey of anthropometric characteristics of 3356 elderly male and female subjects from the Italian population concurred with work of Well's *et al's* (2008) finding that stated waist circumferences became larger whilst hip circumferences decreased. This has implications for garment development in that circumferential values alone are not sufficient when developing garments for an older female demographic and that pattern construction needs to address the lengths/depths between girth measurements to assess waist position in order to accommodate a mature female body shape.

This change in the waist shape and definition has implications for garment development, as circumferential values alone are not sufficient when developing garments for an older female demographic. Pattern construction guidance needs to address the lengths between girth measurements to assess waist position and to accommodate a mature female body shape. However, these lengths need to be identified for this demographic and bodyscanning technology is the ideal media to use to help discern this. 3D-bodyscanning technology can offer these length values but without a clear visual indication of the waist on a mature body frame, i.e. a natural indentation, it is difficult to target where the waist is actually situated for individuals, based solely on the topology of the skin or shape of the body. Therefore, this thesis maintains that more specifically defined descriptors of the body surface topography combined with participant engagement within the anthropometric process would help remedy this.

Body measurements are the precursor to pattern development and size chart generation (Watkins, 2011; Beazley & Bond, 2003) and recognition of the above outlined body changes, which can occur in varying degrees, would support a modification in anthropometric practice for mature women aged 55+. This, in turn, would yield more accurate body measurement, garment patterns, size charts and, ultimately, a garment with superior fit potential facilitating improved functional and aesthetic requirements that would address some of the fit concerns mature women have.

2.3.4 Segments of the torso – the waist

Gill *et al* (2014a) acknowledged that, of the many potentially difficult landmarks to find on the body, the waist was possibly the most problematic for both young and mature individuals. This was due, in part, to the many definitions of the waist within literature sources and the fact that the waist region normally occurred in an area of soft tissue with no visually obvious skeletal or muscular clues to its location.

Kapandji's (2004) guidance concerning the physiology of the joints, and in particular the trunk and vertebral column, substantiate that the waist curve is controlled by a configuration of two internal and external oblique muscles which, lying on a slanted formation together as seen in *Figure 2-10* and overlaid forms a trellis like structure as illustrated in *Figure 2-11*. It is this structure which determines the hollowness of the waist and gives it this outward curved appearance (Kapandji, 2004). Therefore, if these oblique muscles lose tone or have increased subcutaneous fat surrounding them, as can be the case when an individual ages, the waist shaping would be less defined. It could be proposed, therefore, that an individual's perception of where their waist was situated could differ from that of predetermined definitions. This could present further issues particularly when developing garments to cover that portion of the body.

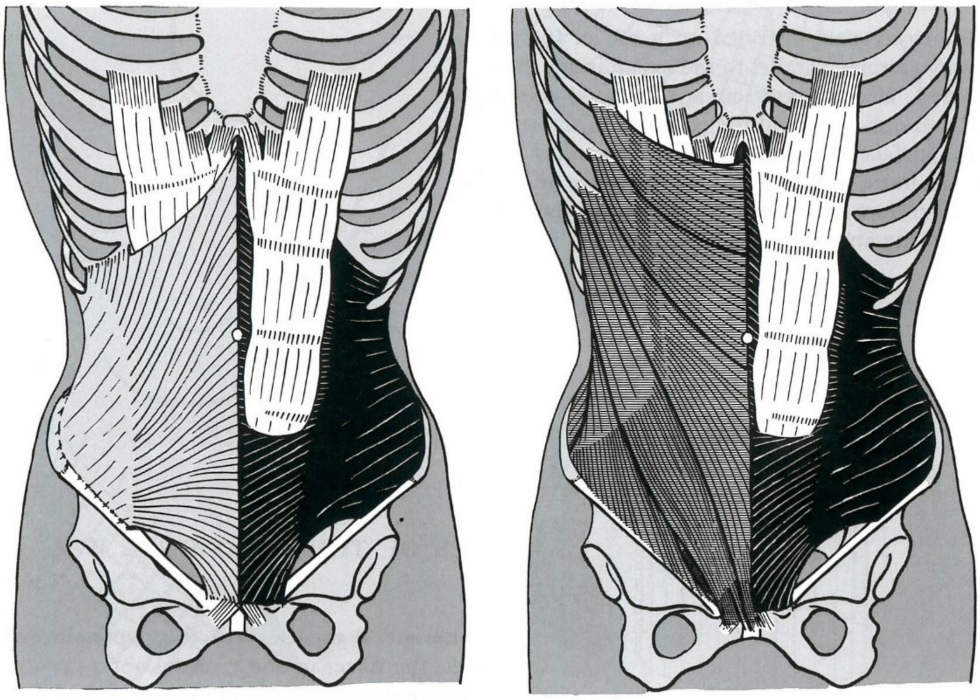


Figure 2-10 Internal and external oblique muscles of the waist source: Kapandji (2004)

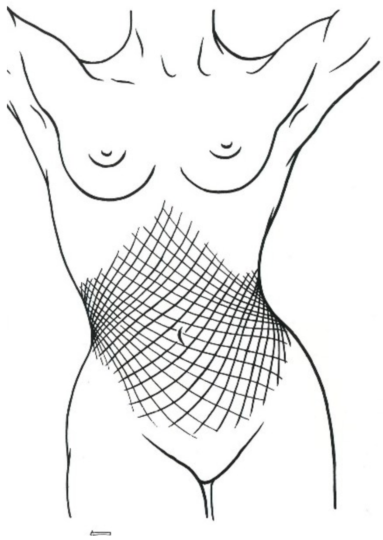


Figure 2-11 Trellis-like structure of the trunk muscles source: Kapandji (2004)

Gill *et al's* (2014a) recent study explores existing waist definitions to find the most appropriate for clothing purposes. Their work commenced with a review of existing waist definitions suitable for clothing product development from both academic and clothing industry resources. Using these resources, they establish and write different waist definitions within the automated measurement software that accompanies the TC² scanner. Working on the premise that the waist had no discernible landmarks, from a visual perspective, from which to use a reference point for non-contact measurement methods, they initially used the general medical definition of the waist as a starting point. From this, they sought to explore automated waist placement accuracy using a variety of definitions.

They recruited a convenience sample of 106 women aged 18-71. Manual measurement techniques and instruments were employed to identify each participant's mid waist point height from the floor using the medical definition of the waist point - defined as midway between the lowest palpable rib and the top of the iliac crest (Gill *et al*, 2014a). The height of this manually derived waist was recorded. This process enabled the work to set a benchmark from which the 17 waist placement definitions – culled from literature and clothing industry sizing guidance - were analysed and written as automated landmarks to be used in the TC² scanner. Scanner waist definitions that placed the waist height nearest to the manually derived measurement were deemed appropriate for that individual, and were collated for later statistical analysis (Gill *et al*, 2014a). Results of this analysis suggested that the definition, which used the small of the back plus 2cm, tended to place the waist height at a height similar to the manually derived waist height. Gill *et al* (2014a) also acknowledge that different waist landmark definitions need developing, as one definition may not be suitable for all genders and body morphologies, something that this thesis maintains is the case for a mature women. Gill *et al's* (2014a) study is important, as it recognises that not all waist landmark definitions are suitable for everyone, and it attempts to explore how to improve the accuracy of the scanner's landmark positioning by utilising the semantics of each definition alongside the scanners software user interface to enable the software to more accurately evaluate the skin surface terrain. What is noteworthy about Gill *et al's* (2014a) work was the fact that the benchmarks for waist position were determined using manual measurement techniques and that the study required the participant to self-palpate their body using proprioception and some verbal guidance to locate the area described as the upper and lower limits of the waist region.

The technician then checked this. It was this proprioceptive knowledge that formed the basis of the waist position benchmark from which all other waist definitions utilised within the scanner software were compared.

Gill *et al's* (2014a) work implicitly demonstrates that manual measurement techniques can be utilised to improve the accuracy of landmarking within non-contact 3D bodyscanning systems. It also implies that proprioceptive knowledge of one's own body is useful in the determination of landmarks such as the waist. Where the work is limited is that it does not acknowledge that the UK population contains individuals who could have a changed posture and spinal architecture due to ageing or, in more extreme cases, osteoporosis. This condition could mean they no longer have an explicitly discernible gap between the bottom rib and the top of the iliac crest, making the medical definition of the waist unsuitable for them.

Manual anthropometric practice provides the opportunity to allow participant engagement, permitting the participant to guide the technician to the area where they believe particular anatomical landmarks to be, which is beneficial for individuals with changed spinal architecture. Accordingly, in the absence of the opportunity to discuss this with the participant – in the case of non-contact measurement systems - the person undertaking measurements at present requires clear visuals of the underlying bone, muscle and fat structure and clearly written landmark definitions with reference to the underlying skeletal or musculature structure for a greater variety of body morphologies to be able to verify and validate each landmark. This thesis ascertains that such information is not presently available within anthropometric guidance (2.2) and so further research is necessary to determine how non-contact landmarking and subsequent measurement extraction could be improved using participant input/engagement. Research of this nature provided the potential to develop written descriptions appropriate for an older demographic, which could be used for training and/or the development of more accurate 3D-bodyscanning algorithms. TC^2 has the data interface to allow new definitions to be written. However, bodyscanner models differ in their facilities and some may not have an interface, which allows new landmark definitions to be written by anthropometric practitioners.

2.3.5 Proprioception - participants self-selecting landmarks for anthropometric measurement

A number of different academic articles from disparate fields of clothing (Song & Ashdown, 2013; Haffenden, 2009; Gill *et al,* 2014a) or medical application (Rim *et al,* 1990; Guerra *et al, 2012*; Wang *et al*, 2003) have explored self-reported body measurement to determine their reliability and validity.

Rim *et al's* (1990) early study of 140 women aged 41-65 years employed manual anthropometric measurement of the waist and hips and a questionnaire to test the validity of self-reported measurement of waist and hip circumferences. Participants were lightly clothes for the first stage of measurement to protect modesty. Medically trained anthropometric technicians measured participants at the region of the umbilicus, for the waist, and the largest circumference, for the hip, using a tape measure. Participants then measured themselves six months later and recorded the values within a questionnaire. Both the technician and the participant also recorded weight and height so weight gain or loss could also be included within the final calculations at the analysis stage. The study found that both waist circumference measurements, first recorded by the technician, and then the participant were approximately the same with no over and underestimation. This finding suggests that the participants believed the waist to be in the same area as the region located by the trained technician. It also suggests participants were able to successfully locate this area for measurement months afterwards. Finally, it highlights the umbilicus is a distinct feature on the body to use as a guide for waist measurement particularly for an older demographic.

Guerra *et al's* (2012) more current examination of anatomical location for waist circumference measurement used a sample of 51 older adults aged 60-85, primarily to determine adipose fat mass around the waist area. Their research indicates that waist landmarking is problematic in older subjects whose body morphology displays excess abdominal visceral fat. It also acknowledges that even in the fields of medicine, where a deep understanding of the body's physiology, topology and anatomy is a requirement, there is no consensus on the best anatomical location for the waist. Their exploratory study proffered ten waist definitions culled from literature to demarcate the waist on each individual by a trained technician. Their study was interesting in that it used palpable skeletal regions alongside easily identifiable surface body attributes as landmarks for the waist. This study, not unlike that of Gill *et al* (2014a), implies that the only way to find the waist on their chosen demographic was to touch/palpate the participants' body surface. This thesis maintains that engaging with the participant in this way during the landmarking process also provides the opportunity for verbal participant confirmation that the marked out area correctly aligns with their perception of where their waist is.

Song and Ashdown's (2013) survey of American women aged 18-35 assessed the reliability of participant's self-perceived lower-body size and shape using 3D-bodyscanning technology to compare scanned body shape against the shape the participants believed themselves to be. The research focussed on the lower torso and legs, as according to Ley *et al* (1992), this is the region of the body most prone to fat deposition for this age cluster. During Song and Ashdown's (2013) study participants were requested to consider this region of their body and rate each segment of the torso and legs using terms such as slim, average and curvy or full and appending a value to each response. Participants were scanned and their data was compared to the rated survey responses. This enabled statistical analysis of both subject perceptions and numerical scan data, successfully using a mixed method approach. Both sets of findings were compared using a standard developed from the dimensional data of SizeUSA alongside measurements from the ASTM D5585-95 sizing system. The study found variance in the perceived measurements for waist height in all respondents but the most variance was observed in the grouping who felt their body displayed a fuller silhouette against the waist height measurements from SizeUSA. This indicated the waist height MEP definition used in the SizeUSA survey differed from where the participants felt their waist position was, with most variance in subjects who had a fuller figure and wear larger sized garments.

Wang *et al* (2003) explored how four differing and widely used waist definitions could impact on the location of the waist. Their study, though targeted at medical professionals, used a sample demographic of 111 males and females aged 7-83 years to measure waist circumferences using four waist definitions. Although the sample was broad in terms of age and small in terms of the sample number, it clearly highlighted that, depending on the words and descriptions used within the definition, the waist circumference will be placed in a different location giving a different circumference reading each time.

Haffenden's (2009) work provides more targeted insights into the perceptions of older females whose body morphology displays a less defined waist position. The study, not unlike that of Song and Ashdown's (2013) methods, employed a mixed method approach using, initially, online questionnaires from a large sample set to gather broad opinions and moving on to semi-structured interviews, a measurement survey and statistical analysis for a much reduced sample of three women. Haffenden (2009) recognised that the waist was a contentious area because large women do not conform to a standard hourglass shape. The work also highlights that participants are knowledgeable regarding their own body shape and are able to articulate their shape clearly using visual analysis of their body surface contours as well as proportional linear measurements. The study, though small scale and mainly focused on knitted garment fit for individuals, is significant in that it acknowledges new protocols need generating when devising a measurement system for women who do not have a clearly defined waist, and that this is possible using participant knowledge of their bodies. From this therefore, it can be suggested that individuals have a firm sense of their own body size and shape and, more importantly for this thesis, are capable of self-assessing their body for key measurement positions as they have unique proprioceptive knowledge of their body.

2.4 Body measurement guidance and pattern construction methods

Pertinent and accurate body dimensions are a requirement for accurate pattern making. Pattern making commences with the development of a simple garment block. The block is a flat 2D geometric shape that represents the body's measurements plus the addition functional ease (Gill, 2009). Ease is defined as the extra measurement added to the body size to allow for body movement, extension and expansion (Chen *et al,* 2008; Gill & Chadwick, 2009).

As body measurement is a precursor to block pattern development, it could be argued that the details provided for body measurement within such pattern guidance need to be explicit for the resultant block pattern to fit comfortably, and present the body in an aesthetically pleasing way. The methods within each pattern cutting publication have different instructions (McKinney *et al*, 2012). For flat 2D methods, this is normally presented in written terms and visual descriptions of the areas of the body from which to extract particular measurements from (Appendix C), the amount of body measurements required, and how they are then mapped and linked to each other (Appendix F).

Aldrich's (2008) earlier editions on pattern cutting for womenswear provide meagre anthropometric guidance, which consists of one page containing a stylised schematic of a slim and upright female figure surrounded by recommended measurement placement points (Appendix C: 11.1.1) bearing no definition or practical location guidance.

On a positive note though, Aldrich's (2015) latest edition does include extra information in the form of a size chart for mature women that has increased measurements for the waist, hips and front shoulder to waist for the larger sizes. This addition demonstrates an acknowledgement of body shape change in these regions but the publication mainly discussed standard body measurements in relation to sizing systems and the book offers pre-developed size charts to use with its block development guidance, in a much similar vein to its earlier publications.

Shoben and Ward's (2010) revised pattern guidance manual uses a comparable female schematic (Appendix C: 11.1.9) to that of Aldrich (2008), of idealised female form. Areas requiring measurement are numbered and there is a degree of guidance detailing the use of manual measurement tools, such as a tape measure. However, the term landmark is omitted and the areas of measurement are not all explicitly defined with some of the definitions, such as the half across back, using a generic measurement value of 10.5 cm down from the nape of the neck. It can be argued that this measurement description is more applicable to a garment than that of the human body as garments are normally manufactured to a strict set of values contained within a size chart whereas the human body is much more variable. The work also implies that measurements surrounding the armpit region are problematic and although there is some guidance on how to extract armhole girth and armscye depth they concede that it is probably better to use the pre-determined size chart supplied with their guidance. This mode of guidance is vague even for a standard body morphology and can obstruct a student from learning how to take accurate measurements for flat pattern drafting, which according to McKinney *et al* (2012) and Knowles (2005) are essential for a well-fitting pattern block.

Haggar's (2004) measurement guidance (Appendix C: 11.1.711) utilises a schematic of a slim, standard sized young female but this time in a posed posture, which is noteworthy, as later in the book Haggar (2004) advises that the anthropometric/pattern practitioner should evaluate posture as a part of the measurement process.

More recent anthropometric guidance, such as that of the Bunka School, for pattern construction recommend that the person being measured should stand straight with relaxed shoulders, arms at sides, and the head held in the Frankfort plane (Bunka, 2008; 11.1.3). The bodice block pattern is widely developed using this posture for body measurement and the resulting fit assessment of the block exercises the same upright static stance (Joseph-Armstrong, 2010).

On a positive note, Haggar's (2004) guidance (Appendix F) recommends taking many more depth measurements than either Aldrich (2008) or Shoben & Ward (2010). If length measurements are combined with those of the circumference it would reasonable to expect that the block pattern would more closely reflect an individual's body shape as well as dimensions. This would be sensible when developing patterns for individuals with specific body shape traits. This makes Haggar's (2004) guidance an improvement on the previously discussed publications who omit depth measurements. Nevertheless, Haggar's (2004) guidance is still deficient in that the definitions of the landmarks are absent and instead a pre-determined size chart has been supplied in a similar vein to Aldrich (2008) and Shoben and Ward's (2010) publications (Appendix C). Upon scrutiny, Haggar's (2004) guidance appears to also cater for a standard body morphology and size, implying by omission that once again older women were not accommodated within this publication.

Knowles' (2005) pattern making guidance offers more measurement guidance (11.1.8) than the previously publications discussed above, in that its guidance is for both the mannequin/stand and the human body. This thesis maintains that measuring a human being is more preferable to measuring a mannequin/stand using manual techniques for two reasons. Firstly, the person can engage with the technician taking the measurements, thereby facilitating greater accuracy in the process. Secondly, generic mannequins/stands, such as the ones displayed within Knowles's (2005) publication, appeared overly upright, with a hourglass shape, high bust point and upright posture which indicates a more youthful physique which not appropriate for everyone.

Chunman-Lo's (2013) more contemporary pattern development guidance, aimed at a student audience, also uses a female mannequin/stand as part of its measurement instruction (Appendix C: 11.1.6). The mannequin/stand is comparable to the one used by Knowles (2005) and Stanley's (1979) earlier pattern construction guidance (Appendix C: 11.1.10). Chunman-Lo (2013) provide discussion of both average and personal measurements but its actual measurement guidance definitions refer to points on an imaginary garment and not on the landmarks of a human body. More emphasis is given to the list of average measurements, which, demonstrates that Chunman-Lo's (2013) method would not be easily utilised for individuals whose body size and shape vary from what is evidently thought of as the average within their publication.

Measuring a mannequin/stand accurately can result in a pattern and a block/garment that accurately fits the stand but not one that would accurately fit a human being. This practice would only work if the stand's surface geometry and dimensions were established using an individual's body size and shape ensuring a made-to-measure fit much like the practice used by haute couture industries (Chunman-Lo, 2013). Such industries can practice both flat pattern and direct modelling or draping methods to build pattern/garment blocks to exact body morphologies. Publications that utilise modelling or draping techniques provide minimal or no generic anthropometric guidance as the practice involves moulding the fabric around the human/mannequin/stand to form a garment template. Stanley (1975), Leto-Zangrillo (1990) and, more recently, Abling and Maggio (2009) are three publications that illustrate this point, with all using modelling practice for their bodice block development. Although Stanley's (1975) guidance does include flat pattern drafting with a rationale that 3D modelling practice forms an initial part of the pattern development learning as it enables a student to become familiar with the human form. Stanley's (1975) guidance advocates an understanding of human body topography but the measurement guidance is minimal in detail (Appendix C: 11.1.10). Landmarking a real human body is omitted and the publication uses a standard dress form to illustrate the key measurements for the development of a size chart for flat pattern development, which does not easily align with her earlier ideas.

Abling and Maggio's (2009) guidance is comparable in that it features both modelling and flat pattern drafting methods (Appendix C: 11.1.4). However, its focus is more about the visual dialog between the design and technical process and so the images and information used is based on women of an idealised size and shape. Leto-Zangrillo's (1990) guidance directly targets women whose body size and shape fall outside of accepted averages – which could apply to a mature female demographic - and it asserts that the practice is ideal for all body sizes and shapes as the proportions of the block template originate directly from the surface of the body (Leto-Zangrillo, 1990). Working directly on to the human body would broaden a practitioner's knowledge of anatomy and surface topology as well as extend their learning of the working properties of fabrics and how they interact with the skin topology and joint junctions. This would then make the recording of body dimensions less central to the process.

Bray's (1986) measurement guidance utilises a slim, posed figure (Appendix C: 11.1.5) similar to that of Haggar (2004). This time however the figure is wearing a dress, as the publication was written for dress pattern development only. This visual indicates it is acceptable to measure a participant fully dressed to make initial basic blocks. However, to be able to effectively find the correct areas - the anatomical landmarks to take the measurements from - the participant needs to be minimally clothed so the practitioner or technology that is measuring the participant could effectively appraise the skin surface (BS EN ISO 20685:2010). Additionally, taking measurements over clothes (such as a dress) does not give a skin surface measurement that are required for a close fitting block. Bray (1986) asserts that anthropometric measurement needs to be simple so a pattern practitioner can understand it, stating that fit can always be adjusted later on in the patterns development. This is noteworthy as no fit amendment guidance is provided within her publication. There are some written details of how to measure an individual and it appears that only eight measurements are needed for bodice development. Interestingly, none of these measurements involve the armscye which is a distinct attribute within a bodice block. Landmarks are not explicitly referred to within the publication and measurement definitions, such as the hips being placed both at the fullest part of the hips, are also given a standard range of 22cm down from the waist position. This definition appears to be a mixture of both body and garment definitions and takes no account of distance lengths between key body dimensions. Bray (1986) acknowledges that taking accurate body measurements is challenging and that it is not easy to take readings from a moving surface that had dips and curves, which is why, perhaps, the body measurement portion of this publication is vague and lacks clear direction.

Beazley and Bond (2003) (Appendix C: 11.1.2), Beazley (1997), Kunick (1984), (Appendix C: 11.1.12) and Bunka (2008) (Appendix C: 11.1.3) offer more clarity regarding anthropometric guidance compared to the above discussed publications. They all provide a level of detailed written and visual instruction alongside a list of landmark definitions, which refer to gross anatomical reference points on the body from which skin surface measurements can be taken (Kouchi & Mochimaru, 2011). The figures used in both Bunka (2008) and Kunick's (1984) publications are photographs of women dressed in normal underwear – although Kunick's (1986) looks very dated - which allowed the skin surface to be seen. Beazley and Bond's (2003) method used a schematic of the body, which lacks anatomical detail so an appraisal of the skin surface is not possible using this image alone. Beazley (1997), however, did produce an earlier academic paper that provides a level of instructive anthropometric survey guidance, which could be used in conjunction with the Beazley and Bond (2003) book. It is unfortunate though the paper is not referred to within the textbook as not all clothing practitioners, particularly those in industry, would have access to academic journals, which require a fee to view. The images used with Beazley's (1997) paper were photographs and so were very clear. Conversely, as the participant being measured wore a leotard, the landmarks of the torso were not clear as they were covered up. Furthermore, Beazley and Bond (2003), Kunick (1984) and Bunka (2008) use visuals of standard sized female subjects who do not display body deviations away from the norm, so their guidance would be difficult to reinterpret on a body morphology that had changed significantly from what the clothing industry considered as standard. Moreover, when looking at pattern development guidance and more specifically how the collected body measurements are used, the Beazley and Bond's (2003) method is the only one which uses more direct body measurements and which can be easily applied using pattern design software (Appendix F). Bunka's (2008) block construction method uses only four measurements, which are based on proportions of the bust, similar to the methods described in Vouyouka's (1996) publication (Appendix F).

Using proportions of a key body dimension to develop a block pattern is akin to tailoring practice (Bray, 1986). However, Bray's (1986) guidance cautions against such practice as she asserts it is a practice more suited to structured or standardised outerwear garments. This thesis asserts that using proportional calculations of key dimensions for other body measurements makes assumptions about the individual's body size and shape. It also restricts how the block can be adapted at this stage to accommodation an individual's body size and shape. Consequently, generating block patterns for a mature female using Kunick (1984), Vouyouka's (1996), (11.1.13) or Bunka's (2008) measurement guidance would again present challenges for a mature women whose body size and shape has significantly moved away from the clothing industry deem a standard size and body shape.

2.4.1 Pattern amendment guidance: target audience

Pattern amendment guidance, both as standalone publications and as additional chapters within pattern development literature, appears to target what it termed 'individual figure types' (Aldrich, 2008: 177), figure problems (Aldrich, 2008; Betzina, 2003), variations from ideal proportions (Liechty *et al*, 2013; Palmer and Alto, 2007) or non-average body types (Apple, 2005). All terms that have negative connotations and view garment fit issues because of having a non-standard body size and shape. Liechty *et al's* (2013) comprehensive work surrounding fitting and pattern alteration, discussion and proffered solutions confirm that classic Greek vertical proportions express ideal body proportions as a ratio of 2:3, with the total body height divided into five equal sections. This was expressed as two sections containing the top portion of the body from the tip of the head to the waist and the final three sections commencing at the waist and finishing at the feet. Liechty *et al* (2013) added that individual physical forms rarely fitted this ideal, which raises the question of why is it still being applied. Joseph-Armstrong (2010) add that clothing manufacturers and retailers' ideal standard body proportions are not necessarily based on real people, and exist as a body form/figure or set of body measurements.

Much of the guidance from both pattern construction literature chapters (Aldrich, 2008; Bunka, 2009; Beazley & Bond, 2003) or standalone garment fitting literature (Betzina, 2003; Palmer & Alto, 2007; Minott 1969; Threads, 1996; Morris & McCann, 1997; Morris and McCann, 2001; Apple, 2005; Liechty *et al*, 2013) require a pattern maker to re-engineer the pattern, often after the first draft has been developed and is complete. This may be a consequence of using proportional measurements and not direct body measurements and, more specifically, body segment lengths. That is not to say that all pattern development literature has moved away from the application of direct body measurements in its block development. Gill and Chadwick's (2009) exploration of ease allowances included within bodice pattern blocks use a practical approach, whereby five construction methods were chosen and each bodice and sleeve block realised as a paper template to facilitate comparative analysis of both the methods and the pattern dimensions. Apart from determining ease allowances and ease placement within the blocks, they also conclude that not all drafts require the same level of direct body measurements, that the measurement nomenclature differs as well as the detail of measurements definitions, which this thesis maintains is still the case. Their work also observes that block shape varies, adding that different drafting methods might suit different body shapes and posture, especially in the case of Armstrong's (2010) method, which provides theories of body contouring, dart intake front and back and discussion of key figure types or classifications within populations (McKinney *et al*, 2012; Gill, 2015). Gill and Chadwick's (2009) main findings determine that there are variations of ease allowances both in the front and back in each method and although they theorise how this would impact on garment fit they do not actually toile the patterns up to explore how this impacts directly on the body or mannequin/form. This was something that was undertaken by McKinney *et al's* (2012) later research and which gave the pattern/body relationship somewhat more clarity. However, what is still not transparent or even discussed is the issue of how accurate the measurement guidance is and whether the definitions are suitable for a broad age range. McKinney *et al's* (2012) work on pattern making theory is comprehensive and it covers many of the main European and US pattern development literature sources. A portion of their work states that even though pattern development practice is explained in these texts in the form of theoretical statements of concept relationships, which vary in detail between authors, there is no consensus on wearing ease allowance. In fact, the details of how ease is calculated is omitted from them. This indicates that modern pattern construction practice centres on experiential/tacit knowledge that it is difficult to communicate, even when designing a block for a standard body shape.

2.5 Anthropometric studies of mature females

Mullet *et al* (2001) provide context for the utilisation of anthropometric surveys, the development of sizing standards and grading systems within their textbook guidance of grading practice. Their work mentions and confirms the first manual anthropometric survey of women specifically for the development of a sizing standard for use ready-to-wear garments was undertaken by O'Brien and Shelton and was sponsored by the US Department of Agriculture in 1941. They maintain that this large scale survey (over 10,000 female participants) provided body measurements from 60 locations on the body. They comment that initial analysis of the recorded data meant four different subgroups/body types were ascertained based on key length and girth measurements. The subgroups/body types were termed by O'Brien and Shelton (1941) as juniors, misses, half-sizes and women's. Each subgroup was then further divided into a range of between seven and ten sizes depending on the subgroup/body type. A calculation of the statistical averages of each specific size group then determined a set of body size specifications to fit a segment of the population. These sizing specifications form the first sizing standard in the US (PS 42-70 Sizing Standard) and, back then, provided clothing manufacturers with a basis from which to size their patterns for their ready-to-wear garments using grading systems based on averaged increment values from one body dimension to the next adjacent body dimension (Mullet *et al*, 2001).

Ready-to-wear garments based on statistical average measurements of many people are currently more prevalent than custom-made clothing - clothing that was specifically sized to fit an individual (Mullet *et al,* 2001) - for purchase on the High street. It is therefore it can be deduced that ready-to-wear clothing is not going to fit every single individual (Mullet *et al,* 2001) and this is why research into improving garment sizing standards, pattern construction and fit preferences has been ongoing for all demographics as population body size and shape does not stay static.

Previous research concerning sizing standard appraisal/improvement (Patterson and Warden, 1983; Woodson and Horridge, 1990; Goldsberry *et al,* 1996), garment pattern development and fit preferences (Richards, 1981) for a mature female demographic has undertaken manual anthropometric surveys using various novel methods, due in part to the changes in body shape and size as part of the ageing process discussed previously (2.3).

2.5.1 Manual anthropometric studies of mature women

Patterson and Warden (1983) determine their own sizing system for females aged 65+ based closely on the previous manual anthropometric methods used by O'Brien and Shelton's (1941) work. Patterson and Warden's study (1983) was necessary as O'Brien and Shelton's (1941) work (2.5) represented less than 2% of the population aged 65+. Due to age related body change and a reluctance to be seen in a state of semi undress, Patterson & Warden (1983) found it necessary to tailor their methods and equipment to enable accurate anthropometric data extraction. Participants wore lightweight shift dresses in an effort to protect their modesty, which made the location of landmarks around the crotch region not feasible although this is not explicitly discussed in Patterson and Warden's (1983) study. The waist region was also obscured by the clothing and so was not visible, which made landmarking of that region difficult.

Both Gill *et al* (2014a) and Beazley's (1997) later work covering manual anthropometric practice allow participants to self-locate sensitive or difficult to locate landmark regions such as the crotch point or waist via verbal prompts. However, Patterson and Warden (1983) did not state whether there was any such verbal interaction.

During the course of Patterson and Warden's (1983) work a number of problems arose. Difficulties in the location and measurement of the shoulder slope angle became apparent. Subjects' shoulder angles sloped forward; there was increased curvature around the cervical portion of the spine, with excess flesh making visual and tactile location of the landmarks difficult. Therefore, in an effort to obtain accurate shoulder slope measurements modified equipment was devised and employed. Effective use of the equipment required it to be balanced on the subjects shoulder and this was not always successful, particularly if the shoulders were acutely sloped. The accuracy of the measurements taken over additional garments and using modified equipment that was not ideal for every body size and shape, could not, therefore be guaranteed to be completely accurate although the study does acknowledge this.

As Patterson and Warden's (1983) work attempted to create new standards, it is reasonable to expect that lower torso measurements would be included in the study. This was not the case as their work omitted ten measurements concerned with the crotch and high hip areas of the body, measurements that had previously been included in the O'Brien and Shelton (1941) study. These omissions resulted in a lack of data necessary for trouser block development or trouser fit. Patterson and Warden (1983) missed an opportunity to compare their landmarking methods against the previous O'Brien and Shelton's (1941) survey and although they do discuss the changes they were required to make, details in the form of visuals and landmarking definitions are absent making it difficult for later studies to adopt their methods. Patterson and Warden's (1983) study, though limited in some details, provide early insights into anthropometric procedures and protocols for a 65+ demographic. Their work demonstrates that anthropometrics for an older female demographic can, and, indeed, needs to be adapted to suit the change in the skins surface terrain.

Woodson and Horridge (1990) later work used a small scale manual anthropometric survey of mature women aged 65+ to provide comparison against the then current sizing standard (PS 42-70), and to also determine how the collected data then impacted on pattern shape and fit. The study is significant as it ascertained how changed body shape then impacts on pattern shape. Woodson and Horridge's (1990) sample size was small, nearly half the size of Patterson and Warden's (1983), and no justification was offered for this reduced sample size. It could, perhaps, be concluded that the researchers had recruitment difficulties, an issue that also affected the previous anthropometric studies discussed in this thesis.

Again, due to issues of modesty, Woodson and Horridge (1990) had to develop a way of extracting the measurements while allowing the participant to be semi-clothed. They developed a device they called the Body Graph. This enabled the collection of not only vertical and horizontal measurements but also contour information of neck and armholes, which is important information for shaping pattern blocks. The device consisted of a series of computer generated measurement strips that were placed over the participants key areas of measurement such as bust, waist and hip. They formed a grid over the body and according to the researchers provided more information on body contours and posture but still in a numerically linear format. Information concerning openings and suppression was also provided using clear plastic adjustable strips and shapes, which were placed, in suitable regions on the participant's body. This customised equipment provided more detailed information that could be incorporated directly to a basic pattern block. These blocks were then compared to commercial patterns from Vogue and Butterick by overlaying the pattern pieces and examining the measurements and shapes. Woodson and Horridge's (1990) main findings indicate that commercial pattern companies and the current sizing standard used then by retailers did not accommodate the body size and shape of this selected demographic sample. Furthermore, their findings also indicated that the targeted demographic displayed body morphological changes, which are linked to ageing and that this had a direct effect on the pattern shape. The study is significant in that it highlights that adjustments to patterns for an older demographic is not be confined to width and length measurements only and that non-standard posture and increased body curvature needs to be assessed and accounted for at the pattern development stage and not incorporated as a fit adjustment after the initial block has been drafted. This is substantiated by the knowledge that the researchers needed to develop specialist devices to be able to first accurately measure posture and second to estimate different types of seaming and darting to accommodate this.

What is not clear from Woodson and Horridge's work (1990) is how they located the key measurement areas, the landmarks. There is no discussion of anatomical landmarking as participants were measured over long sleeved leotards. Woodson and Horridge (1990) effectively utilise anthropometric methods to gain further insight into ageing body posture, however the nomenclature used for the extracted measurements are pattern and not anatomical terms, perhaps because these terms were also used in the original O'Brien and Shelton (1941) survey.

Goldsberry *et al's* (1996) large scale US based manual anthropometric survey of females aged 55+ provided what could be argued to be an overdue specific set of sizing standards for this demographic. Previous work by Richards (1981) which focused on garment styling and fit preferences for women aged 65+ indicated that mature females required clothing that was sized and shaped specifically for them, as well as establishing that mature women are knowledgeable about garment styling and how to present their body in an aesthetically pleasing way. Unlike the studies of Patterson and Warden (1983) and Woodson and Horridge (1990), Goldsberry *et al* (1996) used a younger demographic, aged 55 and onwards, as their starting point. This implies that the researchers felt age related body shape/size change appears at a younger age.

Goldsberry *et al's* (1996a) study also took the opportunity to gather fit perceptions from the 6652 participants – a sizable sample. Their questionnaire mirrored previous research conducted by Richards (1981) who, as discussed above, explored mature women's fit preferences. The results of both Richards (1981) and Goldsberry *et al* (1996a) work were similar in that participants had specific fit preferences which were governed by their age and body shape and that these participants had found it difficult to find well-fitting clothing.

Goldsberry *et al* (1996) developed a garment that would provide body coverage whilst still allowing the measurement process to continue. This implied that they also encountered issues of modesty with participants unwilling to remain in a state of semi-undress for the measuring process. The garment that participants wore was an all-in-one Lycra suit that the researchers termed the 'Ultra Body Suit'. This suit was pre-landmarked with a grid work of lines and intersections to indicate body landmarks that would inform the data collectors where to place the tape measure. The study did not explicitly indicate whether there was any verbal interaction between the participant and technician so it is unclear if the participant could have used proprioceptive knowledge to locate difficult to determine landmark points and feed this back. The use of this body suit introduced error into the survey, as it was unclear if the lines of the body suit were positioned accurately on the participant's actual body landmarks (Bye *et al*, 2006).

A study by O'Haire and Gibbons (2002) focusing specifically on manual landmarking methods and demarcation primarily for practitioners involved in clinical practices, stated that manual landmarking required visual analysis of the skin as well as physical palpation of the skin surface to determine where the landmark is. Their findings indicated that palpation alone was not reliable and showed error even between practitioners who had been clinically trained to define and locate body landmarks.

Goldsberry *et al's* (1996) suit covered the skin so the research concludes that practitioners tasked with locating the landmarks were required to palpate subjects as finding them using observation alone would prove difficult.

Goldsberry *et al's* (1996) study is significant as it illustrates that changes in body morphology can occur at a younger age, 55, and its findings contributed to the generation of a new standard, the ASTM D-5585, which was purposely developed for women aged 55 years and over. The large-scale nature of the survey also allowed Goldsberry *et al* (1996) to identify and categorise subjects into various body shape types based on the measurements of bust, waist and hip. Seven figure types were established with the rectangle being the most predominant. According to Goldsberry *et al* (1996) it was found that the measurements of the rectangle body shape from their survey were considerably greater when compared to the PS42-70 standard in the following areas of: abdominal extension, waist, armscye, bust point, back width, chest width, hip and hip arc indicating shape change occurred predominantly in the torso region.

Goldsberry et *al's* (1996) study provides a great deal of dimensional and shape information for the chosen demographic. Unfortunately, the data gathered was intrinsically flawed due to the use of the Lycra body suit. As with the previous studies concerned with either pattern construction or measurement guidance, it also lacked details of how the landmarks were defined and then applied them to the changed topography of the body. Anatomical landmarking, in this study and the aforementioned work of Patterson and Warden (1983) and Woodson and Horridge (1990), was not discussed in any detail. This is remarkable as landmarking the body is the first stage of manual anthropometric practice (Croney, 1980; Beazley, 1997; Bunka, 2008) as these landmarks define the area for measurement (Carrere *et al*, 2002), and it is these measurements which are critical to accurate clothing pattern development (Bye *et al*, 2006). Therefore it is reasonable to expect that they be given greater importance.

In summary, O'Brien and Shelton (1941); Patterson and Warden (1983); Woodson and Horridge (1990) and Goldsberry *et al* (1996) all conducted female-only manual anthropometric surveys (of different sample sizes) for the clothing industry that have included or predominately been for women aged 55+. All these studies encountered one or more of three outlined issues primarily linked to manual measurement methods which are: inaccurate landmark location and demarcation; the unsuitability of the measurement equipment; and the participants' reluctance to be seen in a state of semi-undress, which for some of the studies, resulted in small samples. Therefore this thesis concludes that these three issues need careful consideration for any future anthropometric surveys targeting a female demographic aged 55+.

2.6 UK adult anthropometric surveys using 3D bodyscanning technology

Manual anthropometric surveys, when compared to non-contact anthropometric surveys, can be time consuming, expensive and prone to human error (Fan *et al,* 2004). 3D-bodyscanning technology according to Bye *et al* (2006) presents the greatest scope for analysis of different body shapes and sizes. The privacy afforded by this technology's methods, its non-contact nature and the speed of its measurement extraction is considered ideal for measuring a 55+ female demographic (Ashdown and Na, 2008), as it appears to counter problems associated with modesty (Lee *et al,* 2012).

2.6.1 SizeUK

The most recent large scale anthropometric survey using 3D bodyscanning technology for clothing development purposes within the UK is the SizeUK survey. This survey was a collaborative effort between retailers, government agencies, academics and TC² (Sizemic, 2010) to gather anthropometric data from 11,000 adult males and females (Apeagyei, 2010). One hundred and thirty non-contact and 8 manual measurements were collected from the UK population aged 16-90 (Sizemic, 2010), although it should be noted that the distribution of demographics is not freely available to view by the public so it is unclear how many participants were female and aged 55+ years.

The survey used 3D bodyscanning technology (the TC² scanner) to scan 11,000 participants both in both standing and sitting postures, making the survey sizable and significant for the clothing industry in the UK. The TC² scanner validates a standing posture which is why it offers handholds and foot positioning as part of its configuration. In addition, its online marketing material does not explicitly state it will measure individuals in a variety of different postures. Therefore, it is difficult to ascertain how the sitting measurements were taken using this technology without clear details, of which the SizeUK information is lacking. Participants were also asked to complete a market research questionnaire which gathered data surrounding clothing issues, shopping habits and preferences, lifestyle habits which included health & fitness, occupation and employment and ethnicity.

The aim of the SizeUK survey was to collect measurement data to update UK retailer's sizing systems and to ultimately improve the fit of clothing products (Sizemic, 2010) by capturing and extracting anthropometric data from a large UK male and female sample so that retailers could be more informed of the general public's body dimensions. As a number of prominent High Street retailers such as the N Brown Group Plc, Arcadia Group, and Marks & Spencer contributed to the survey (Sizemic, 2010, Apeagyei, 2010) it is reasonable to expect that the data was being used in the development of their clothing, via size charts, for all adult demographics as this is generally what anthropometric data is used for by clothing practitioners.

2.6.2 The limitations of the SizeUK anthropometric survey

This thesis maintains the SizeUK survey has four main issues, which are not highlighted or discussed in any current literature sources. Firstly, the data is not in the public domain and is only available for viewing/analysis through the purchase of a Data Licence (Sizemic, 2010). Secondly, it is difficult to ascertain how effectively the public were segmented in terms of demographics, body shapes and sizes and how these segments were proportionally represented as this information is omitted from the SizeUK reports. Thirdly, the proprietary nature of all 3D-bodyscanning systems results in a lack of clarity surrounding the algorithmic landmarking programme (Simmons and Istook, 2003) so it is unclear what algorithmic calculations were used to automatically landmark individuals, and, in turn, what definitions for each landmark were used to drive these calculations. Fourthly, quality in terms of image capture and resulting measurement depends on physical limitations of the scanning device (Mortara *et al*, 2006). For example Daanen and van de Water's (1998) survey found some hardware configurations had difficulties capturing specific regions of the body. They recommended that the suitability of the hardware configuration should be assessed against the requirements of a particular application and that not every scanner was suitable for every application. Therefore, static 3D-bodyscanning units that have in-built lights and sensors, which remain at a fixed arrangement - a particular height and distance apart - may not always effectively illuminate and capture all body types. The SizeUK survey used static TC^2 3D bodyscanning units to collect data and that meant sensors and cameras remained at a fixed position for every scan, which, according to Daanen and van de Water's (1998) conclusions, suggests that this data may not be accurate.

2.6.3 Reported protocols for the anthropometric survey process

Bougourd and Treleaven's (2014) research and experience of conducting national surveys for the clothing industry (the researchers were actively involved in the Size UK survey) outlined some of the protocols that need to be in place when undertaking an anthropometric survey. Their work is valuable as it can direct those new to anthropometric surveys. Bougourd and Treleaven (2014) examined a number of different international surveys to establish if there were commonalities within their survey process. Their findings indicate that most surveys have a system in place to address recruitment, data protection/ethics, data capture, data storage and data validation, and in each of these areas, the authors provide a level of detail. What is lacking, however, in Bougourd and Treleaven's (2014) work are clear details on how to benchmark landmarks/measurements and validate scans for particular demographics as the information provided is for generic surveys only.

Bougourd and Treleaven's (2014) research explicitly draws on their own experience of dealing with companies who would want to protect the results of their survey, and the manner of their work appears to support the idea of keeping the data confidential unless a fee is paid. This thesis recognises that it is important that sensitive data such as participant information is kept private and not in the public domain. However, as the public supplies their data for anthropometric surveys it is not unreasonable to expect more detailed information concerning the survey process and results of survey to be made available for public viewing. With this in mind, whilst Bougourd and Treleaven (2014) support the idea that survey results should only be released if paid for, they do concede that few organisations undertaking anthropometric surveys produce an explicit reflective report of their study, which, this thesis maintains, would be highly beneficial in highlighting potential problems for others undertaking comparable anthropometric studies.

2.7 Practical overview of the current 3D bodyscanning technology

2.7.1 The technologies used to illuminate and capture the human image

There are a number of different proprietary 3D-bodyscanning systems on the market (Daanen & van de Water; 1998, BS EN ISO 20685:2010; D'Apuzzo, 2007; Brogue, 2010, Apeagyei, Daanen & Ter Haar, 2013; King 2014, Bragança *et al*, 2015; Appendix H; Table 2-1).

Application software.									
Scanner	Cyberware	4ddynamics	4ddynamics	Vitronics	Vitronics	TC2	SizeStream	SpaceVision	3dMDbody
Type	WBX	Mephisto EX-pro or CX-pro	Gotcha	Vitus Smart LC	Vitus Smart XXL	KX-16	3D body scanner	Cartesia	Flex8
City	Monterey<comma> CA	Antwerp	Antwerp	Wiesbaden	Wiesbaden	Cary<comma> NC	Cary<comma> NC	Tokyo	Atlanta<comma> Georgia
Country	USA	Belgium	Belgium	Germany	Germany	USA	USA	Japan	USA
Web	www.cyberware.com	www.4ddynamics.com	www.4ddynamics.com	www.vitronic.de	www.vitronic.de	www.tc2.com	www.sizestream.com	www.space-vision.jp	www.3dmd.com
Price indication (US$)	240<comma>000	60<comma>000–120000	10<comma>000	37<comma>000	65<comma>000	10<comma>000	15<comma>000	20<comma>000	190000
Technique	Laser line	Structured light projection	Structured light projection	Laser line	Laser line	Infrared (IR)	Infrared	Laser structured light	Stereophotogrammetry
Scanner space (w * d * h) (cm)	261 * 235 * 290	300 * 300 * 160	NA	220 * 220 * 260	210 * 210 * 290	114 * 168 * 200	107 * 165 * 216	198 * 229 * 240	440 * 346 * 225
Scanned volume (w * d * h) (cm)	130 * 50 * 200	100 * 100 * 200	NA	90 * 90 * 2100	120 * 120 * 2100	90 * 70 * 210	95 * 70 * 215	70 * 60 * 200	79 * 76 * 213
Scan heads	4	4–8	4–8	3	4	16	14	9	9
Point-point distance	<2 mm	<1 mm	<1 mm	7/cm3	27/cm3	1 mm	1 mm	3 mm	<1 mm
Scan duration (s)	17	2	1	12	12	3	6	2	0.002
Output format	.ply	.ply	.ply	ASCII/.obj/.stl	ASCII/.obj/.stl	Derived body dimensions	Derived body dimensions	.obj	TSB/OBJ/STL/WRL/PLY
Color	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Moving components	Yes	No	No	No	No	No	No	No	No
Application software	Converters	No	No	(www.)humansolutions(.com)	(www.)humansolutions(.com)	Clothing related	Clothing related	no	various
Remarks						PC included			4D scanning possible

Table 2-1 Proprietary 3D-bodyscanning systems specification Source: Daanen & Ter Haar (2013)

Optical-based laser or white/structured light 3D bodyscanners scanners were first light source technology used (Appendix G) and were scanners of choice for past anthropometric survey purposes as seen in Appendix A.

A review of international anthropometric surveys (Appendix A) by this thesis indicates that three proprietary brands have dominated this market. Those being Cyberware, Vitus and TC², with TC² used in SizeUK and SizeUSA surveys (Appendix A), although Cyberware has since ceased trading.

Bodyscanning systems have advanced (Daanen & Ter Haar, 2013, King, 2014) and are now adapting new technologies such as Microsoft Kinect, which works using speckled infrared (IR) light across the skin surface and depth sensor cameras (15.1.3). Of all the brands available TC² and Human Solutions are the two brands that have been mostly utilised for previous anthropometric surveys (King, 2014), although scanning technology is developing and other brands such as Styku and Size Stream can perform similar tasks (Appendix H).

Although there is variability and incomparability of measurements between scanner brands (Simmons & Istook, 2003), their common intention is to capture the participant's body surface data and extract anthropometric data in a valid and reliable manner (Apeagyei, 2010). King's (2014) review of the process and application of 3D bodyscanning for national sizing surveys confirms (not by name, perhaps because King works for TC²) that other brands of 3D bodyscanners do exist on the market, and that they offer increased portability, a point confirmed a year earlier by the work of Daanen & Ter Haar (2013). She concludes her review by saying if these scanners are not using optical-based laser or white light technologies their data accuracy would need validation over time. An interesting statement, as TC² itself uses Infer red (IR) light and depth sensor technology, implying that, perhaps, time and tested results will prove whether this form of body surface illumination is any better at data capture.

All 3D bodyscanner brands operate in two stages, data capture and data analysis. Data capture is the initial stage where a subject is scanned and then the system develops a 3D body model. Data analysis is in the form of measurement extraction, which can be conducted any time after scanning, and during the creation of the body model. Although

3D-bodyscanning technologies may vary in their methods of data collection and measurement extraction, in essence they all strive to capture a person's body image and convert it to a digital body model ready for measurement extraction (Apeagyei, 2011).

Daanen and van de Water's (1998) early survey of proprietary 3D bodyscanning hardware found both optical-based laser and white/structured light technologies operate in a similar way. Daanen and Ter Haar's (2013) work revisits 3D bodyscanning technologies in a survey format and confirms that this is still the case. Both forms of bodyscanning technology use one or more light sources to project a line or pattern onto the human skin surface (Appendix G). Cameras capture the image of the projected line or pattern and the software extracts depth information from the captured images (Daanen & van de Water, 1998) into X, Y and Z coordinates from the skin surface (Brogue, 2010, Fan *et al*, 2004).

2.7.2 How each light source works to capture the image

According to von Übel (2017) white or structured light (so called white light because it uses a white bulb) is used to illuminate a fringe/grid pattern over the skin surface (*Figure 2-12*). This fringe/grid and phase/waves of light are modified in terms of the dark and light width/spaces and the angles each phase of light produces which is then captured by each the sensor placed nearby within the scan area, which feeds image processing.

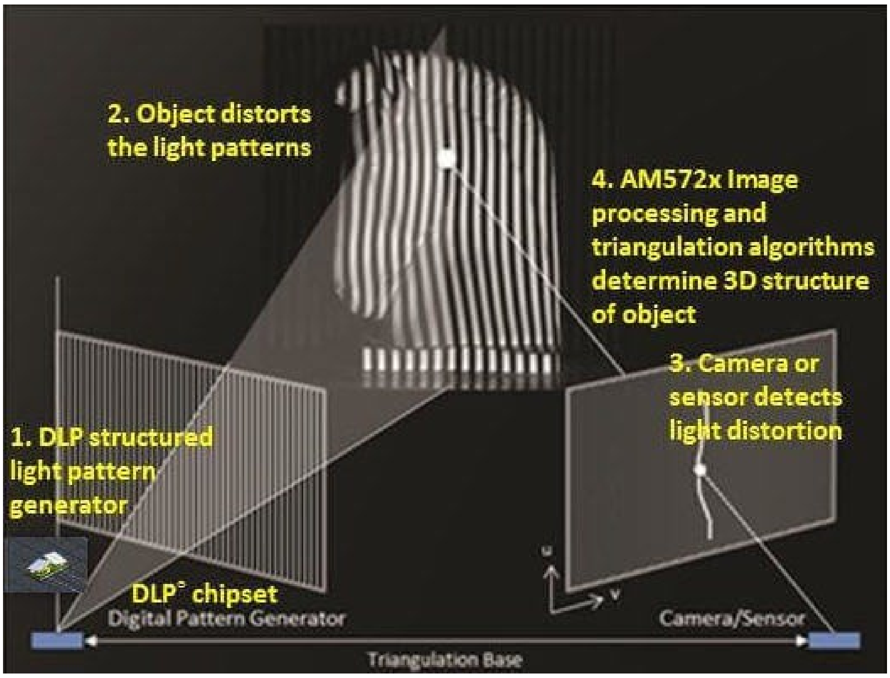


Figure 2-12 How white/structured light operates source: von Übel (2017)

According to Clarkson (2011) laser light scanning systems work by moving a stripe/beam of laser light over the skin surface. The peaks and troughs of the skin surface deform this stripe/beam and changes the way it is seen/captured by the nearby sensor (*Figure* 2-13). The distance from the skin surface to the sensor is measured using these distortions in readiness for image processing.

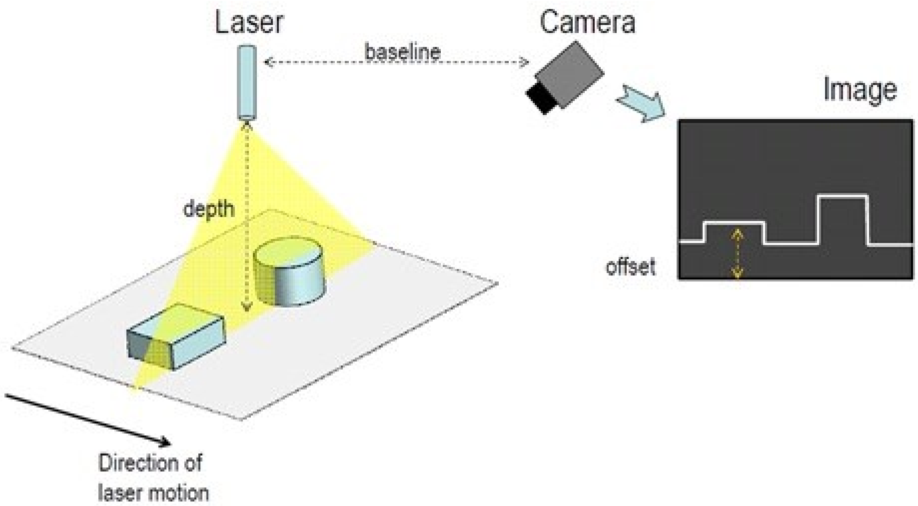


Figure 2-13 How laser light operates source: Clarkson, (2011)

According to Clarkson (2011), infrared (IR) scanning systems scatter preconfigured pattern of infrared speckled light dots over the skin surface (*Figure 2-14*). These dots vary in size and each size is optimised for use in different depth ranges and carries a unique surrounding area that the sensor can recognise. The sensor collects the new configuration of IR dots and the software can compare this configuration against the original stored in its software.

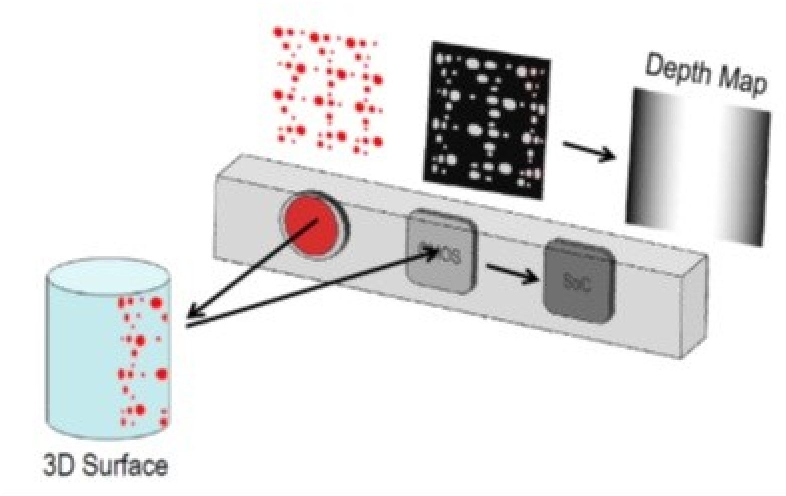


Figure 2-14 How Infrared (IR) light operates source: Clarkson, (2011)

2.7.3 How 3D bodyscanning software processes the captured image data to form a virtual skin surface

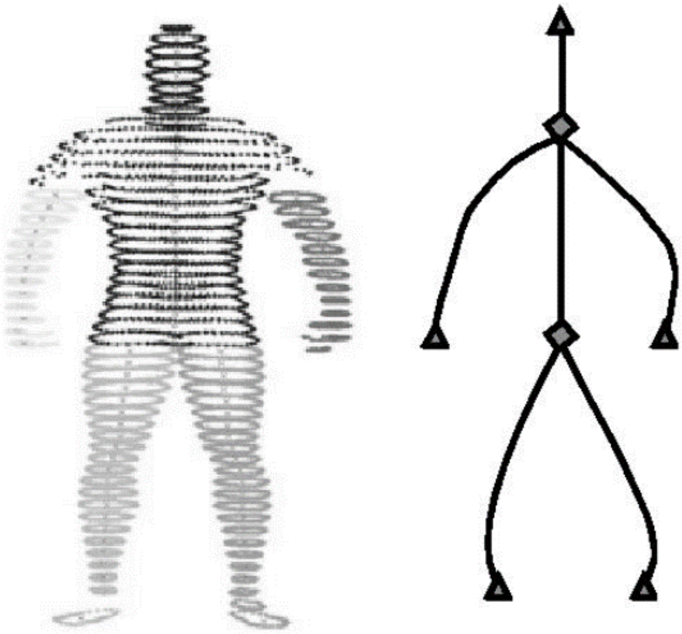


Figure 2-15 An example of a Reeb graph of a human body shape and its discreet Reeb graph (image on the right) used within 3D bodyscanning technology source: Xiao et al (2003)

Both Xiao *et al* (2003) and Biascotti *et al* (2007) discussions of 3D image processing confirm that the initial stage of image processing commences with the production of a Reeb graph (*Figure 2-15*) before its initial body model point cloud is assembled. Biascotti *et al* (2007: 5) describe a Reeb graph as 'compact shape descriptors that convey topological information related to the level sets of a function defined on the shape'. To those not familiar with these terms this means, the Reeb graph provides a virtual skeleton around which the body model is formed and shaped.

The body model's point cloud shape is formed around the Reeb graph and is then aligned to a mean shape/body template (*Figure 2-16*) using Procrustes rotation (*Figure 2-17*). Procrustes rotation works in tandem with both the Reeb graph and the initial body model point cloud as it is a registration procedure to measure the precision of 3D point cloud coordinates by superimposing repeated images in such a way that the square distance between homologous landmarks is minimised (Kohn & Cheverud, 1992). It can therefore be deduced that both the Reeb graph and Procrustes rotation procedures are based on standardised human morphology within the TC² bodyscanning software system. This is because on a basic level, the Reeb graph is developed to see a head, neck, full upright torso supporting two arms and two legs with accompanying appendages, and the Procrustes rotation will be programmed to see the same. Consequently, as the mean target shape to make the predetermined template does not match the body shape of a person with a non-standard body morphology the bodyscanning system cannot provide complete body measurements. This use of standard templates highlights a limitation, with potentially varied and non-standard bodies not being catered for within the TC² bodyscanning system.

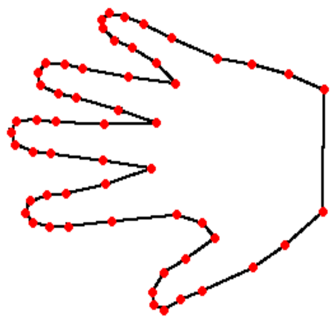


Figure 2-16 The body model template (the mean shape) source: Ross (2004)

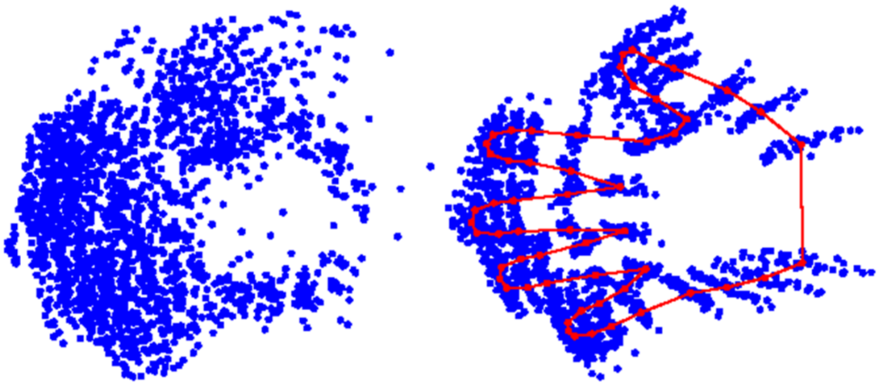


Figure 2-17 Procrustes Rotation - the blue point cloud approximately forming the shape and the registration process which aligns the point cloud around the body model or mean shape Source: Ross (2004)

These processed virtual skin surfaces are range images, similar to contour maps (Fan *et al*, 2004) which convert the captured data into point cloud coordinates (1st image in *Figure 2-18*) in virtual 3D-space (Fan *et al*, 2004). The cameras are situated close by the light source and acquire a number of images of the body from different perspectives (Lovato *et al*, 2009). More than one camera is utilised to reduce shading effects on the body surface (Daanen & van de Water, 1998) as reconstruction of the body model can be difficult (Istook *et al* (2011). Some configurations of light source/sensors are not suitable for obese/corpulent participants as shadowing can occur (van Stralen *et al,* 2003). These perspectival images are patched together by the software to form a whole 3D surface allowing views from different angles (Lovato *et al*, 2009, Istook *et al,* 2011) from which measurements can be taken (4th image in *Figure 2-18*).

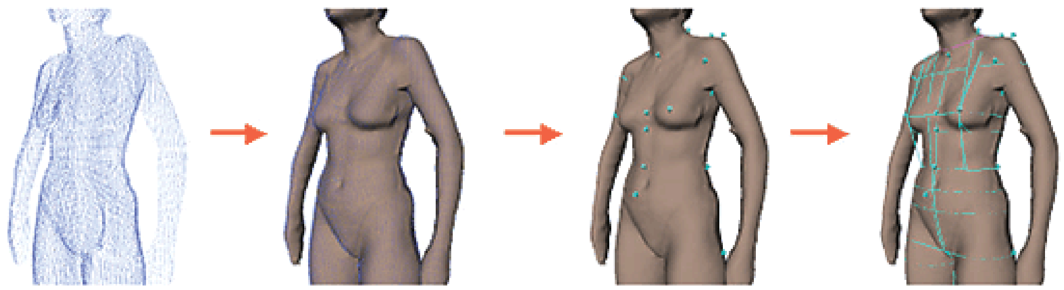
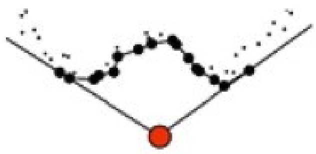


Figure 2-18 Point cloud image, closed surface, landmarking and measurement extraction Source Treleaven & Wells (2007)

2.7.4 <u>3D-bodyscanning accuracy and limitations</u>

Although 3D bodyscanning technology is improving (2.7) it cannot be perceived as error free (Bragança *et al,* 2016; Daanen and Ter Haar, 2013; Buxton *et al,* 2000) and therefore completely accurate given the variation in scanner brands specification (*Table 2-1*) and the application of the technology. A number of studies (Simmons & Istook, 2003; Carrere *et al*, 2001; Chen, 2007; Daanen & Hong, 2008, Veitch, 2012) highlight issues of precision and accuracy within 3D-bodyscanning technology across a number of proprietary systems.

Buxton *et al's* (2000) early paper discussed reconstruction and interpretation of 3D body images and within this examined one such issue, relating to the scanner hardware, which was missing (occlusions/holes) or manifested superfluous data (noise, *Figure 2-19*) appearing in the resulting point cloud image. The occlusions/holes arise from shading where the light source cannot illuminate an area of the body surface which according to Istook & Hwang, (2000) and van Stralen *et al* (2003) can be attributed to poor posture adoption or body tissue skin folds. However the noise - defined as points with are present within the scan data but which do not lie directly on the body surface (Buxton *et al*, 2000) - can be attributed to body movement artefact according to both Daanen & van de Water (1998) and McKinnon and Istook (2002). Which can result from an inability to remain or keep balanced, possibly due to changes in body symmetry which are connected to the ageing process (Ashdown & Na, 2008). Alternatively, can also be attributed to excess body fat and tissue that can also appear as part of the ageing process. The 3D bodyscanning software does attempt to clean superfluous noise/data from the virtual skin surface using nearest neighbour analysis or point cloud density (Istook *et al*, 2011) but this can vary in its success.



$$a_{\min} \geq \frac{(4m + \frac{\alpha}{2})D + \sigma}{(\frac{\alpha D}{2\sigma} - (4m - 1))}$$

Figure 2-19 The noise is represented as lighter dots floating above the virtual skin surface (heavier dots) source Mehra et al (2010)

Bragança et al's (2016) most recent study explores the anthropometric process (both manual and non-contact) and concurs with Daanen and van de Water's (1998) early belief that the longer it takes to scan a person the more like it is they will move and therefore the opportunity for occlusion or noise is increased. According to Olds and Honey's (2005) study of the usage of 3D body scanner in anthropometry white structured light based scanners such as the old NX16 TC² model are thought to be fast than laser light based scanners. Meaning movement could be picked up more easily using a laser based light source scanner that is not ideal for older participants who may find it difficult to stay still for extended periods. Olds and Honey (2005) also state that although white structured light systems are faster their resolution is lower than that of laser systems. The higher the resolution – the denser the point cloud - of a scanned image the greater clarity of the virtual skin surface. This means the software will have richer information when analysing the peak, ridges and troughs coordinates in order to locate and place an anatomical landmark. Meaning that laser based systems will produce a clearer scan image, which enhances the accuracy of placing landmarks in the correct position on the body. IR structured light source scanning systems (the technology which is used by TC² and Sizestream as seen in *Table 2-1*) are described by Bragança et al (2014) as less accurate than the other two light sources in that its skeleton (Reeb graph) structure is basic, and because of this it is more ideal for use in clothing studies. As mentioned above (2.7.3) the skeleton or Reeb graph has compact shape descriptors that carry topological information of the shape and if this information is basic then it is logical to expect the shape itself to be less detailed in terms of point cloud density which ultimately impacts on landmarking accuracy as the virtual skin surface is less defined. This is perhaps why King (2014) suggests that time and testing the technology will tell if this light source technology is any more accurate than the previous offerings (2.7) particularly for those with non-standard body morphologies.

Simmons and Istook's (2003) survey and comparative analysis of proprietary 3D-bodyscanning technologies focuses on the software capabilities of the technology. Their study found significant variance in the methods used to capture specific body measurements (as can be verified by the specifications in *Table 2-1*) and in the terms used to describe or name those measurements – as confirmed in Gill *et al's* (2014a) later study concerned with defining the true waist position. Their findings suggest that this variance is the greatest problem between the different scanning systems. Lack of standard terms and measurement definitions between scanning systems is indeed problematic. However, this thesis maintains that the fact that standardised generic landmark definitions, taken from idealised body sizes and shapes, have been applied within national surveys to participants whose body morphologies were no longer considered ideal or standard is an even greater problem going forward.

2.8 Non-contact landmarking methods

2.8.1 The origin of automatic landmark definitions

eTCluster are a think-tank of European clothing academics and 3D-bodyscanning manufacturers whose main objective is to propose a framework of standards suitable for integration into 3D-bodyscanning technology (cordis.europa.eu, 2007). Their initial approach drew on traditional anthropometric methods, which uses the practice of landmarking logic to determine the descriptions of start and end points for body measurements as a benchmark. Their collaborative work identified and listed landmarks suitable for clothing construction to be used as descriptors for the automatic detection and location of landmarks within the TC^2 software (Shin & Istook, 2006; cordis.europa.eu, 2007). The definitions they collated for use are generic and originate from previous manual/traditional anthropometric surveys, practice and standards (cordis.europa.eu, 2007; Simmons and Istook, 2003). Olds & Honey's (2005) study concerning the usage of 3D bodyscanners in anthropometry state that traditional anthropometric practice uses landmarking logic, which is a practice which has grown out of late nineteenth century anthropology. They describe the method as being, '[B]one based, static and taxonomic' and not always easily adapted for clothing design, which also relies on estimation of body shape and soft tissue area (Olds & Honey, 2005: 1). They state that 3D bodyscanning practice has the scope to estimate body shape as the technology can scan over the topography of the skin surface. However, using landmarking logic and, in particular, generic manual landmarking definitions on different segments of the population has already been identified as problematic in earlier research such as that of Patterson & Warden (1983) and Woodson and Horridge (1990). With this in mind, it is therefore reasonable to expect that current definitions would not be effective for all body morphologies, a point which is reinforced in the later work of Han and Nam (2011) which will be discussed further on in beginning of section 2.8.3.

2.8.2 Current landmarking methods

Researchers from a variety of disciplines including anthropometrics (Kohn & Cheverud, 1995; McKinnon & Istook, 2002); clothing development (Pargas *et al* 1997; Han & Nam, 2011; Veitch, 2012); computer science (Wang & Chao, 2010; Suikerbuik *et al*, 2004) and statistics (Dryden & Mardia, 1992; Azouz *et al,* 2006), have explored and developed a variety of algorithmic methods to enable the software programmes within bodyscanning systems to locate and/or place landmarks over the virtual skin surface (Appendix M). All the aforementioned share some similarities in that they studies operate a form of 3D image/shape analysis. This may involve the surface vectors/vertices/coordinate points being quantitatively evaluated using pixel colour or vector configuration. The image maybe segmented and/or sliced into regions of the body for planar views and further feature detection looking at the topological and silhouette information. Alternatively, statistical calculation applied to find a landmarks approximate location based on previous location coordinate averages.

This thesis highlights that such disparateness in disciplines suggests that skills sets from interdisciplinary fields are necessary and required to develop 3D bodyscanning technology for clothing application. This also means that if the technology is to be used for clothing product development then clothing practitioners who will use the technology and the suitable landmark definitions as well as the other above mentioned disciplines need to work together to make the technology 'user friendly' for the clothing industry and easily applicable to the task.

The above-mentioned studies took four independent approaches to landmarking using different disciplines skill sets. Some of the images used to support each method in this section are drawn from other secondary sources as not all the cited articles below supply imagery that is of sufficient clarity/resolution to use in this thesis to demonstrate the point:

- 1. Exploration of the virtual surface topography of the body was undertaken by researchers such as Han *et al*, 2009; Ashdown and Na (2008) to find skeletal landmarks clues (Figure 2-8). This method of visual analysis sometimes using angle measurements on screen mimics manual landmarking, the difference being that the virtual skin surface is perceived as a series of quantifiable peaks, ridges and troughs by the software. This methods draws on the traditional practice of observation of the skin surface (via the computer screen), something, which is familiar to clothing practitioners. It is a practice that can be applied to non-standard body shapes if user interface is facilitated with the 3D bodyscanning software allowing the landmarks to be amended by an operator, if needed.

- 2. Han *et al* (2009); Loker *et al* (2004); Azouz *et al* (2006) all used statistical relationships between landmarks. These methods use software prediction and calculation algorithms (for example principle component analysis or pairwise Markov network) to review spatial relationships, and statistically predict the next neighbouring landmark. This method uses mathematically based calculations that 'train' the software (via neural-networks) to predict neighbouring landmarks. The approach requires large volumes of scan data - of which clothing practitioners may not have access to - from all body types to train the software to be able to predict accurately before the method is suitable for general usage. In addition, it also requires a statistician to formulate the calculations and computer engineer to write software compliant computer code and link this to the existing software in the development of the methods.

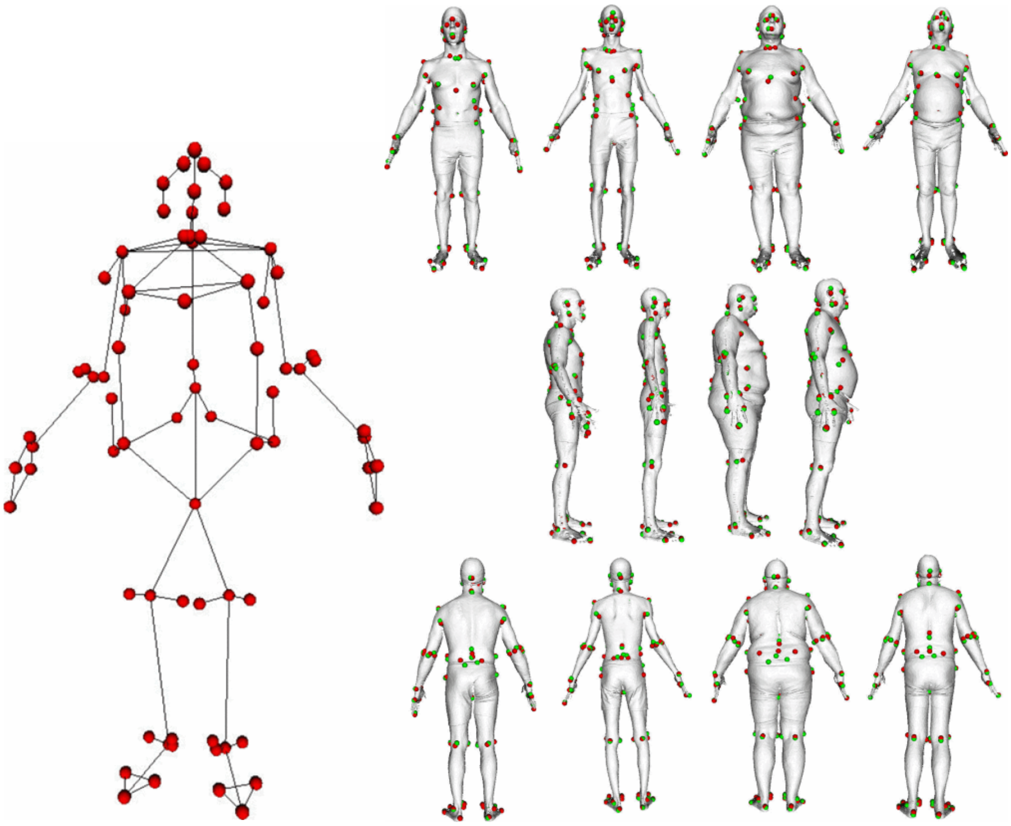


Figure 2-20 The landmark graph and results of landmark location on four human models source: Azouz et al (2006)

- 3. Suikerbuik *et al*, (2004); and Zhong and Xu's (2006) methods use individual body types/parts which are compared to a software selected pre-landmarked template model (*Figure 2-21*) using a curve or function fitting process (*Figure 2-22*). The development of these methods is reliant on a large library of templates developed from scans of individuals who had been manually pre-landmarked and interestingly neither study explicitly states who does this and from what discipline. In addition were either of these methods to be used of a mature female the software would need a large template library of non-standard body morphologies to improve the accuracy of landmarking these women.

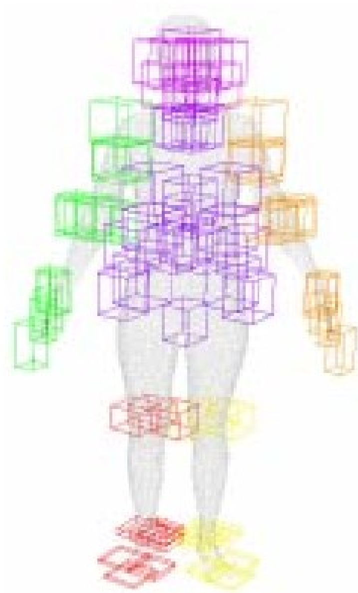


Figure 2-21 Bounding boxes containing landmark templates placed over regions of interest on the body source: Suikerbuik et al (2004)

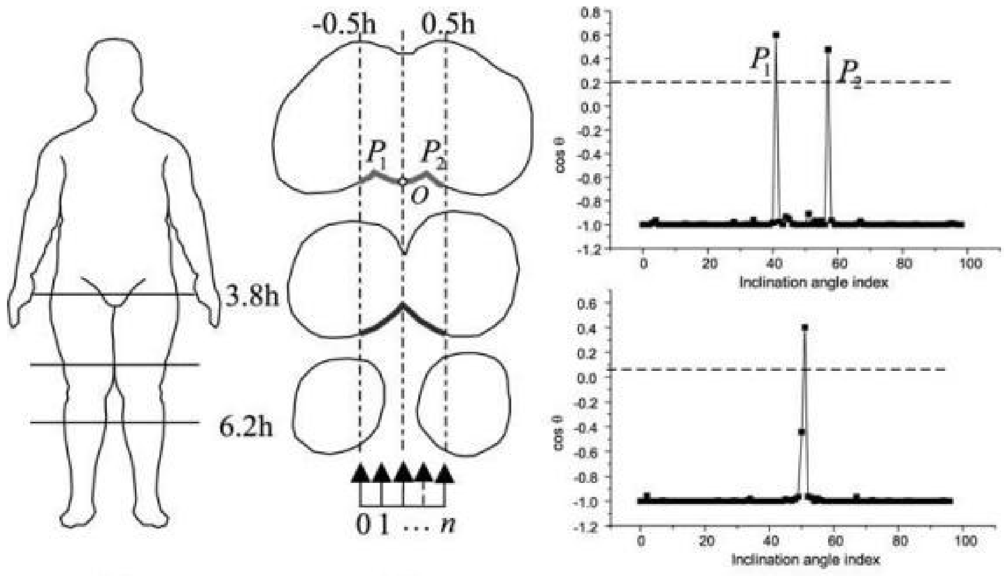


Figure 2-22 Locating the crotch point landmark using slices to calculate the inclination angle between two neighbouring segments on a plot source: Zhong and Xu (2005)

- 4. The work of Robinette & Daanen (2006) and Burnsides *et al* (2003) produced a landmarking method, which is more akin to manual methods and so more familiar to clothing practitioners. Their methods require that participant's landmarks are located manually and are demarcated by an anthropometric practitioner using tonal or cone shaped markers (similar to those in *Figure 2-23*). These markers are then located by the scanner software, which pinpoints the centre of the marker to verify the landmark position as demonstrated in the third image in *Figure 2-23*). This method combines both manual and non-contact anthropometric practice, which a clothing practitioner would find easier to comprehend as it draws on their existing knowledge and skills set of measuring a human body.

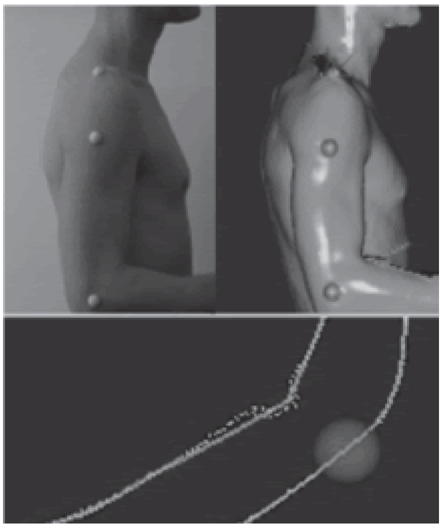


Figure 2-23 Semi-automatic landmarking - as used in the Caesar survey - scanner locating the landmark marker using topographical and colour analysis source: Bragança et al (2016)

2.8.3 Automatic landmarking methods for different body types/morphologies

Han and Nam (2011) identified the need for flexibility within landmark definition algorithms to improve accuracy for non-standard body morphologies. As morphological change generally occurs in the torso for both men and women, their research focused on improving landmarking in this region.

They used landmark height and greatest circumference to enable the identification of landmark locations for different body shapes (somatotypes), which then informed the software of body-type thereby facilitating the adjustment of landmark algorithms to bring about correct placement of landmarks. Their process involved a method of shape analysis which utilised the cross sectioning of scans and an examination of the topography of the vector surface (*Figure 2-24*).

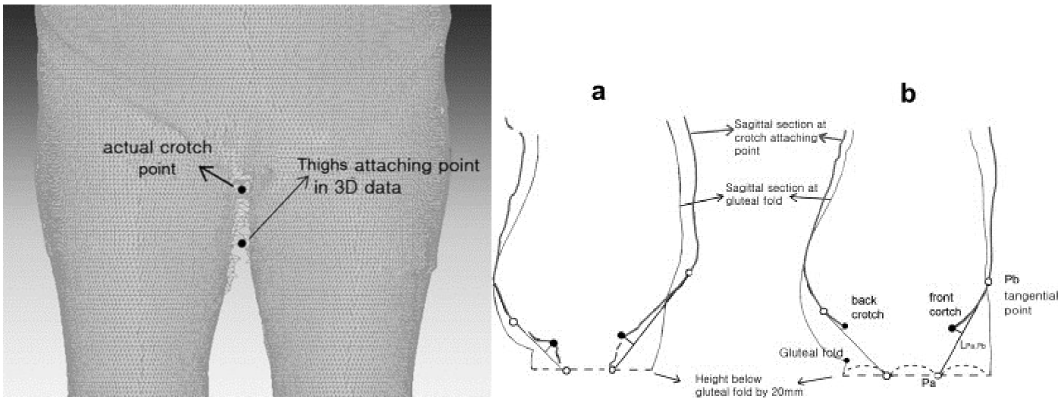


Figure 2-24 Methods of identifying the crotch point using the vector surface and a side-on sliced scan source: Han and Nam (2011)

Their research indicates that accuracy of landmark placement was dependent on the amount of participant information provided. However, landmarking accuracy would have been further improved if the study had applied special landmark definitions - identified during the work - instead of implementing one set of generic landmark definitions. Their automatic landmarking method utilised data acquired by the WB4 Cyberware scanner (Appendix A) used for the Size Korea survey, although it was entirely clear whether the WB4 Cyberware scanner was the only scanner used in this study. Meaning adoption of Han and Nam's (2011) landmarking method would require testing on other types of scanners as scan file types and database interfaces vary between proprietary brands (Appendix F).

Veitch's (2012) work a year later, also explored the appropriateness of specific landmark definitions for women whose body morphology differed from what is considered a standard size and shape. Veitch's (2012) methods compared waist definitions provided by the ISO 8559, 2.1.11 standard (which provided guidance on anthropometric survey and garment construction) and that of the CAESAR survey's preferred waist measurement. The ISO 8559, 2.1.11's waist measurement is defined, as the waist position is midway between the top of the hipbones and the lower ribs for all participants, whereas the CAESAR preferred waist measurement allows participants to self-select their waist position using an elastic band. The CAESAR (Civilian American and European Surface Anthropometric Resource) survey gathered anthropometric data of populations from three countries within the NATO alliance and the data gathered was used for several applications including engineering/ergonomic design and, therefore, was not specific to garment development (Robinette *et al*, 2002).

Veitch (2012) examined automatic landmark placement against participant preferred waist placement (*Figure 2-25*) using the Cyberware scanner which was similar to the one used by Han and Nam (2011) in that both scanner brands use a laser light source. Veitch's (2012) findings indicate a number of things, the first being that the waist for garment development purposes would be better pitched and not straight, for participant's whose body morphology displayed a large abdomen, large breasts and a low bust point. Secondly, Veitch (2014) found the CAESAR preferred waist measurement was more suitable for garment construction which is sensible as women have preferences regarding garment fit (2.10) and like to make decisions about where the style lines – for example the waist band – of their garment would fall on their body. The ISO 8559, 2.1.11 standard waist definition, is perhaps more suited to clinical disciplines which do not use anthropometrics to develop coverings for the body that are developed to present the body in an aesthetically pleasing manner and provide the wearer with comfort. Thirdly, Veitch (2012) also found the choice of measuring instrument effects the measurements taken and finding which has been echoed in the current work of Bragança *et al* (2016). Veitch (2012) found that when the scanner had to use the ISO 8559, 2.1.11 definition to automatically landmark the waist it erroneously placed the waist above or across the bust point on individuals whose body morphology had moved away from what was considered a standard shape and size (*Figure 2-26*). Veitch (2012) concludes that generic landmark definitions are not inclusive of the full range of anatomical variation encountered amongst adult women and that the CAESAR preferred waist positioning method was more successful for locating the waist of non-standard body morphologies.

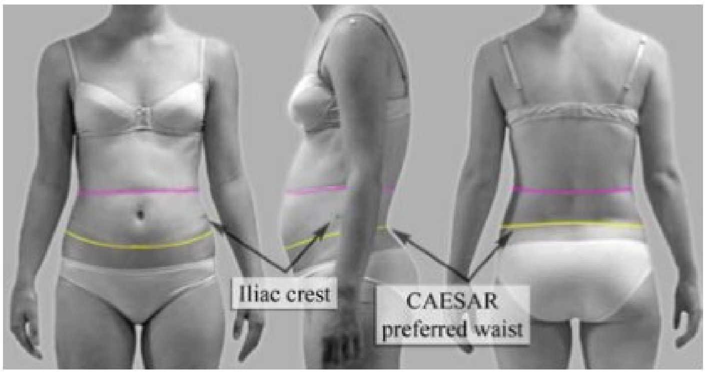
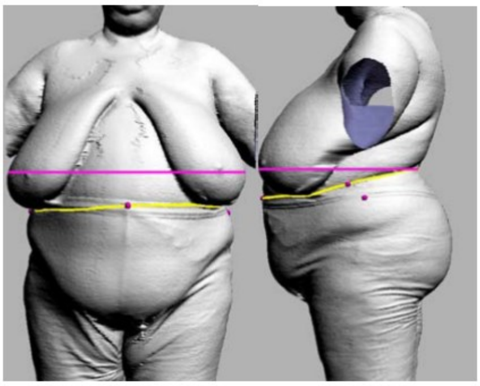


Figure 2-25 Caesar preferred waist position (yellow line) and the ISO waist position (pink line) Source: Veitch (2012)

What is perhaps most notable about Veitch's (2012) paper was the fact that the women measured wore no garments on the upper part of their torso when being scanned, as the sample was part of a breast reduction study whose methods possibly required participants to be scanned without lingerie, as the breast itself needs to be visible. Therefore, it is questionable if scans of this nature are suitable for clothing development. This is because, not wearing a bra meant that some participants' breast points were very low (*Figure 2-26*). Women may choose to wear a bra under their outer garments and this would provide support for the breast, perhaps even adjusting the bust point to a higher position. This change in bust shape and position can influence where either the scanner or the participant positions the waist. Therefore, for scans which will be used for clothing construction it is better for the participant to wear her usual lingerie.



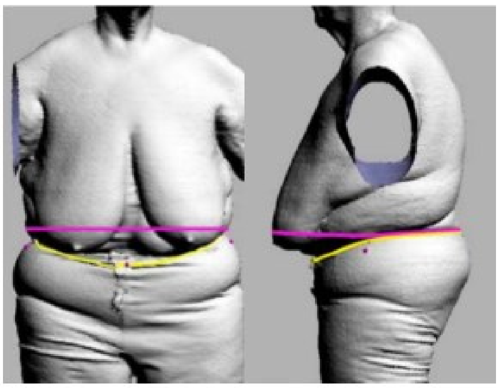


Figure 2-26 Two of the participants with non-standard body morphologies Source: Veitch (2012) study

2.8.4 Validating landmarking accuracy

Robinette and Daanen (2003) - two of many researchers involved in the CAESAR survey - produced a paper in 2003 which attempted to review the project, and provided some details of the adaptations they had to make for the survey to be successful. One of the adaptations discussed involved the speed of scan processing whereby the scanner needed to provide a 3D image of the participant within 5 minutes after scanning so they could validate each scan before the participant left (Robinette & Daanen, 2003). Therefore, this thesis reasons that observational analysis of the image by the CAESAR scanning team appeared to be how each scan was evaluated for accuracy of image capture and measurement placement, which is similar to the approach used in manual methods. During the course of scan image validation, they found that non-contact landmarking and surface measurement for some portions of the body was not accurate enough – perhaps due to the posture adopted as both seated and standing postures were used - and could not be validated. In this instance, the document that they reverted to manual anthropometric methods, as they felt more confident in the resulting measurement readings. Interestingly the CAESAR survey did not scan anyone over the age of 65 and there appears to be no discussion of non-standard body size and shape within the Robinette *et al,* (2002) report.

Kouchi and Mochimaru's (2011) study of landmarking errors and the evaluation of accuracy for both manual/traditional contact and non-contact landmarking methods sought to quantify the landmarking error. The study states that landmarks cannot be precisely located purely by visual evaluation of the surface shape and that accuracy improved when palpation methods were used. Therefore, these methods could act as a benchmark for testing non-contact landmarking definitions in the form of algorithms.

Their study used two landmarking practitioners with varying levels of experience (2 months to ten years). The two practitioners were required to use traditional landmarking definitions and processes on a mixed gender/age sample of 40 participants whose mean age was 35 for males and 32 for females. Therefore, the study did not specifically target any particular demographic, which implies both Kouchi and Mochimaru's (2011) work did not consider that older demographic groups had landmarking accuracy issues due to age-related change in body morphology, and that landmarking error can occur on younger participants.

Kouchi and Mochimaru's (2011) research required the two practitioners to mark landmarks on individual participants using marking mediums that were both visible and invisible in natural light. This process was performed 5 times with a third party checking coordinates of each mark using different light sources to reveal marks not visible in natural light. The work intended to evaluate and define the distance between each mark if the landmarks did not appear to be in the same place even though they shared the same title and definition. Any difference in mark position was measured, recorded and statistically analysed.

The study found that the more experience practitioner positioned their marks closer together; therefore, the distance between the marks on certain landmarks was small. Predictably, the reverse was true for the practitioners with lesser experience. Kouchi and Mochmaru (2011) found that landmarks, whose marks had large distances between each mark and whose body dimension measurement could vary greatly even though they shared exactly the same definition and needed greater clarity in the description of how to locate, position and demarcate the landmark. This work was important as it revealed that landmarking errors are possible on a younger sample of participants even when both visual and tactile senses are employed to detect a correct landmark position and using someone with a considerable amount of anthropometric experience.

Gill *et al's* (2014b) paper, explores the practical applications of 3D bodyscanning for teaching and research. Their work found that information on scan storage, capture, evaluation was meagre, and that 3D bodyscanning technology or any of its accompanying manuals do not provide the validation checks, which occur during manual anthropometric measurement collection. As a result of this finding Gill *et al's* (2014b) paper is the most explicit in providing information in how to identify and amend erroneous landmarks and as it is written from the perspective of a clothing practitioner its recommendations are accessible for those who work in clothing development related industries. It acknowledges that 3D bodyscanning is still a developing technology and that little is known about the practical applications and limitations of its operation, which gives purpose to their research and the development of this thesis. Their research recognises that different systems may require different protocols and that their guidance may need adaptation as it focused on the TC² scanner brand, something which is not explicitly mentioned in work such as Han and Nam (2011) and other papers of this nature. Importantly, they also state that for a clothing practitioner to utilise the bodyscanner effectively for clothing development purposes, they faced a steep learning curve as aspects of the technology and associated processes are unfamiliar and would be outside of their existing knowledge base.

Gill *et al* (2014b) explore both the TC² NX16 and KX16 scanner models software during both teaching and research collaborations, effectively learning how to utilise the scanner as they went about their day-to-day tasks. Their work identifies a number of areas to support the practice of using scanning technology as well as highlighting problematic areas that impede progress. Their paper primarily focuses on developing protocols for pre and post scanning practice and their findings – amongst other things - provide practical guidance concerning scan image validation and data cleansing, which evaluates landmark positioning. Their solutions to scan image and landmark position validation stem from the empirical work undertaken within the Department of Apparel whereby the scanner is used mainly as a survey tool. Their work offers clear details such as the correct file selection, image rotation to check the viability of the point cloud and (grey coloured) closed polygonal mesh surfaces (defined by Volino and Magnenat-Thalmann in 2000 as The simplest data structure for representing geometrical surfaces), and landmark validation using operator judgment, which was reinforced by both the measurement directives found within the scanners software database facility or the manual landmark definitions used in the BS EN ISO 20685:2010 (Appendix N).

2.9 Perceptions of 3D body scanning technology, and mature women's willingness to participate

2.9.1 <u>Younger women's perceptions of 3D bodyscanning and scan clothing</u>

Loker *et al* (2005) sought to examine how women in the US perceive and engage with 3D bodyscanning technology as a tool to extract body measurements. Using a questionnaire they surveyed 203 women aged between 35-55 to determine their perceptions of the body scanning experience and willingness to be measured. The sample was younger and, notably, the entire sample was willing to be scanned and became involved in the process, implying the study had no recruitment issues. As a part of the scanning process, participants were required to wear a Lycra scan suit over their existing lingerie for the whole scanning session (Loker *et al*, 2005). This garment effectively worked like an extra item of clothing and afforded a level of privacy during the scanning process. What is perhaps most significant is what happened once the participant was shown their scan image as this reintroduced an element of discomfort with the process for some participants. Loker *et al's* (2005) findings revealed only 55% of those scanned were comfortable viewing the images on the computer screen, which indicated that the image they viewed was not as they expected and the scan suit did not hide as much of their body as they may have perceived it would.

King's (2014) recent summary of the survey process using 3D bodyscanning states that in the US it is common practice for participants to wear a Lycra scan suit. Additionally, British Standard BS EN ISO 20685:2010 confirms that scan clothing may be used although it asserts that it should not obstruct body landmarks. Providing an additional garment that would be identical in terms of garment styling and attributes for each participant could have enabled the participant in Loker *et al's* (2005) work to experience higher comfort levels within scanning experience and it could also be inferred that providing something so uniform could contribute to the participants feeling more anonymous. Donning a Lycra body suit could benefit some individuals who are sensitive about their body shape and size, as its elastic properties – depending on the Lycra content within the fabric structure - could support the skin and present a smooth body surface but it is unlikely the fabric would fully disguise an individual's body shape. Therefore Lycra scan suits are not the panacea to reducing participant discomfort in viewing scan images.

2.9.2 The limitations of wearing scan clothing

Wills and Bhopal (2009) study, which manually measured 50 men and women to determine the accuracy of both waist and hip measurements taken over light clothing as contrasted with measurements taken on underwear or bare skin, found an average increase of 0.5cm in waist circumference for 64% of the sample, and an average increase of 2.58cm in the hip for 96% of the sample when a participant was manually measured wearing a light garment over their underwear.

The clothing worn differed to that of the Lycra scan suit (which was designed to be close fitting) in that some clothing items were light shirts or trousers that would be a looser fit on the body and could gather under the tape measure. Wills and Bhopal (2010) also implicitly confirmed that landmarking could only be performed on bare skin as no mention was made of marking landmarks over garments. Therefore, it is clear that wearing additional clothing whilst being scanned could impact on measurement accuracy in terms of landmark position and measurement readings.

2.9.3 Mature women's perceptions of 3D bodyscanning

Lee *et al's* (2011) later investigation exploring comfort levels of the scanning process from the perspective of mature women indicated that 64% of their participants were comfortable with the thought of having their body scanned for the purpose of pattern development to improve garment fit. However, when presented with the opportunity of showing their scanned body image to friends or family, women who proportionally weighed more or who had a high BMI score were uncomfortable letting others see their scan. Scanned images can be very realistic and distressing for some women to view (Domina *et al*, 2007). Lee *et al's* (2011) study did not actually scan any of the participants so the results may have changed had participants been required to be scanned as the next stage of the research.

Grogan *et al's* (2015) research investigated long-term reactions to body scanning from women aged between 18-81 years using both qualitative and quantitative methods. These women had been previously scanned during two scanning events for clothing development purposes. Four hundred and fifty six women were sent a qualitative questionnaire of which ninety-one women (significantly less than a quarter) responded and had a mean age of 51 years. Women ranged in body size and BMI scores. The mean BMI score for this study was 25. The authors stated that BMI is not always an accurate measurement as it did not account for muscle mass, yet they did use it as a quantitative means of segmenting and viewing their sample. The UK's National Health Service states that adult women whose BMI is 25+ weigh more than is ideal for their height (nhs.uk, 2014). Therefore, it could be inferred that, on average, the women who participated in this questionnaire were overweight and younger than the mature female demographic this paper is focussing on.

With this in mind Grogan *et al's* (2015) findings indicate that more than half of the respondents were dissatisfied about their body image and 34% stated they felt more negative about their body since they had been scanned. Those that felt positive about their body image were generally more positive about their scanning experience and that concurred with the results in Loker *et al's* (2005) study. Grogan *el al's* (2015) work also confirms Lee *et al's* (2011) finding that some women were concerned about the scan image which could be printed or viewed on screen. Grogan *et al* (2015) expand further on this point by indicating that participants expressed a number of emotions including disbelief, shock or a desire to take up an exercise regime to change their body dimensions and shape. They summarise that when the women were prompted to reflect on the process and its outcomes they generally understood the process could be informative but concluded that 3D bodyscanning cannot be recommended as a means to promoting positive body image as women with low body confidence found either the process or the images a negative experience.

Bragança *et al's* (2015) recent overview of scanning technology suggests that due to improvements in current body scanning hard/software and communication technologies issues of privacy are more pressing as the images are clearer, personal and potentially more invasive as they can be stored, copied and shared. Both Loker *et al's* (2005) and Lee *et al's* (2012) work raises the question of the purpose of the image and whether it needs to be shared with the participant if it will distress them. Women who have been scanned clearly would like to be informed of the results of their scan. However, no study to date has explored the possibility of using alternative images within the body scanning process to either inform the participant of their body size and shape or to allow the participant greater engagement with the scanning process such as landmark position confirmation, which provides another rational for the development of this thesis.

2.10 Mature women's purchasing behaviour & requirements of clothing products

2.10.1 Clothing as a corrective medium for perceived body shape flaws

Research regarding preferences for aesthetic attributes in clothing as a function of both comfort and how individuals view their body image is ongoing. Richards (1981) early research found women over 65 years understood their body shapes and had very definite ideas on how clothing could be seen as a corrective medium to balance out changes in body morphology thereby improving their confidence levels. Later studies such as those of Hurd-Clarke *et al* (2009) and more recently Güzel (2013) whose work involved either interviewing 36 women between the ages of 71-93 or surveying 175 women over the age of 65 concur with Richards (1981). They state that mature women (those over 65 years at least) utilise the styling and aesthetics of clothing to strategically mask age-related morphological change as well as provide comfort and aid movement. Chattaraman and Rudd's (2006) work, though focused on a younger demographic, identified that body size correlated with a desire for greater body coverage, in terms of garment styling. Grogan *et al's* (2013) study of dress fit and body image of younger women (18-45 years) found that either women chose certain dress styles to correct or emphasis a particular body attribute. For example, women whose body shape did not display a clearly defined waist sought to choose clothing, which would provide the appearance of a waist thereby balancing out the bodies proportions. Grogan *et al's* (2013) work demonstrated that the participants felt an hourglass shape with a more defined waist region is more desirable as it is an indicator of a youthful body shape (2.3.3). Hurd-Clarke's (2001) exploration of how older women feel about their ageing body found that some older women could reject or disassociate themselves from their body shape seeing it as almost a shell that is not a part of them, which helped them when having to view themselves in a mirror. Hurd-Clarke (2001) also discovered that older women (65- 90 years) still regard a youthful body shape as desirable and during the study lamented that their body no longer displayed this shape. Therefore, it can be assumed that, if given the opportunity to mimic a more youthful body shape using the medium of clothing, older women would be interested.

2.10.2 Factors which govern mature women's purchasing intent

Holmlund *et al's* (2011) exploration of mature women's garment purchasing behaviour found, through a series of interviews, that this demographic are knowledgeable about their body size and shape. Their study also reveals that mature women are conscious of age related changes to their body morphology and have clear ideas of how they perceived clothes should fit them with these changes in mind. Though focussed mainly on mature women's shopping behaviour and the process of purchasing garment, Holmlund *et al's* (2011) work included discussion of garment fit and body attributes. Notably, the interview discussions included mature women's perceptions of personal waist position compared to the waist positioning on a garment, inferring their sample could evaluate how a garment would fit based on visual observation of the garments geometry in relation to their own body's topography. This information demonstrates that this demographic are well-informed regarding garment styling and how particular styling and cut can enhance the garment wearing experience.

Joung & Miller's (2006) US survey of 386 females aged 55+ explored the relationship between a mature woman's level of social activity, her shopping activity and shopping orientation. Their findings suggests that women who were active in both formal and leisure activities shopped for clothing more frequently and in a variety of ways. Though Joung and Miller's (2005) their sample set was small in terms of the population size in the US, it indicates women who are active are interested in clothing purchasing and would seek garments that satisfy their needs from a variety of sources. A significant finding of the study was the importance of physical appearance a woman places on her image does not diminish with age.

Nam *et al's* (2006) work found a similar response in their US based study of fashion conscious behaviour of mature women. They surveyed 63 women aged 65+ to gather data on fashion awareness and buying habits. Although the sample set was smaller than that of Joung and Miller (2006), Nam *et al* (2006) conclude that even older participants (aged 65 -75) are fashion conscious and enjoy fashionable clothing. Their results were not influenced by the inclusion of younger participants aged 55 – 64, people who were perhaps still active, as they had not yet retired (Nam *et al*, 2006). Rocha *et al's* (2005) exploration of age, gender and national factors in fashion consumption surveyed a convenience sample of 801 male and female participants aged 15+ over three continents. Those continents being the UK, China and Brazil. They found participants aged 55 and over were 'physiologically young' and highly demanding in terms of fashion product attributes. These three studies suggest that women aged 55+ worldwide are indeed interested in fashionable clothing and maintaining a fashionable appearance. Thus, as this population is growing so is the need to provide clothing patterns and, in turn, garments which are pertinent to both their aesthetic and functional requirements.

2.10.3 Body image perception and retailers ideas of body shape and proportions for mature women

Zhang *et al* (2002) and Newcomb and Istook's (2004) research on product attributes and sizing standards suggest fit is the most important and highly ranked attribute. Consequently, an understanding of target consumer body size and shape and accurate size charts was necessary to provide garments that fit well for any selected demographic (Zhang *et al*, 2002, Newcomb & Istook, 2004). Birtwistle and Tsim's (2005) survey of 145 female subjects aged 45+ from the UK found dissatisfaction with garment fit. Their findings seemed to support the notions raised by others (Birtwistle & Tsim, 2005) that garments targeted at a mature demographic were cut to fit a younger body shape. Which suggests that as well as pattern construction guidance, discussed earlier on in this thesis in section 2.4.1, retailers also did not recognise the changes in body posture and dimension as women grow older (Birtwistle & Tsim, 2005) and instead elected to develop garments based on a younger more idealised body shape.

Schewe's (1988) study, in consultation with experts from the University of Maryland's Centre on Ageing, provided details of areas of morphological change on an ageing body, as mature consumers have particular requirements regarding their body size and shape (BSI, 1991). The study, though targeted mainly at marketers and not garment development practitioners, confirms that for retailers to effectively cater for mature customer's, consideration of the notable changes in body dimension and postural change is necessary within the product development process (Schewe, 1988).

Despite the growth in the UK's older population, Joung and Miller's (2002) work concentrating on mature women's clothing preference indicates that clothing retailers often neglect this demographics' needs, preferring to focus on a younger customer. In addition it is also suggested that clothing retailers catering for a mature female demographic (45-60 years) use pattern blocks which reflect the body shaping of a younger women (Hsu, 2009; Birtwistle and Tsim, 2005). If this is typical industry practice, it can be expected that garment fit is an issue within the ready to wear of the High Street.

2.10.1 Designing for an older female demographic and the product development role

Designing clothing for this demographic may be challenging for the clothing industry as mature women are knowledgeable about their body size and shape and have firm ideas about how they wish to present their body using the medium of clothing. The literature (Zhang *et al*, 2002 and Newcomb and Istook 2004) suggests that with age comes a greater wisdom of clothing attributes (especially garment fit). Coco Chanel, a mature woman at his point and a world-class international womenswear designer, indicated (quote on p III) in in an interview for Vogue's December 1969 edition that women look their best when clothing is designed to work in harmony with their body morphology. This is because the comfort this affords is akin to wearing nothing because the garment neither restricts nor engulfs the body. To achieve this is complex, as a clothing designer needs knowledge of contemporary trends and clothing attributes alongside an understanding (perhaps even empathy) of what mature women require from their garments. The clothing business however is changing due to globalisation. Therefore design roles may not only consist of trend/market research and the development of design ideas (Goworek, 2009) but may be required to take on a technical duties which include the generation of a garment specification which include size chart analysis and garment block selection depending on the needs of the company (Hayes *et al,* 2012). This type of technical designer can be termed a product developer (Hayes *et al,* 2012) as their role is broader than that of a designer as it overlaps with other roles which can include the pattern development and construction and assessment of the garment itself (Goworek, 2009; Wren and Gill, 2010 and Tyler *et al,* 2012). It is this role which generates/requires details concerning body/garment dimension, pattern geometry and garment suppression/fullness and it is this role which can prepare (either directly or by direction to others) the garment blocks in readiness for styling. Therefore, it can be argued that it is this more technical role, which is central to ensuring a garment satisfies the garment fit requirements of mature women.

2.10.2 Clothing retailers view of ageing

Twigg (2015), whose research primarily focusses on the three elements of ageing as a concept, the ageing body and clothing choices, interviewed 20 older women - including design directors from M&S, Jaeger, George at Asda and the editor of British Vogue - to explore these elements in greater detail and to establish what is thought of as age appropriate clothing, both within the industry and the wider general public. The study confirmed that providing clothing for an ageing female market is a lucrative business (Twigg, 2015) and that ageing is stigmatised within a western society (Twigg, 2004).

Significantly, her work recognises that retailers often do not want to be explicitly labelled as catering for an older female market, which only reinforces the idea that ageing as undesirable.

Twigg's (2015) work acknowledges women's body shape can change due to the ageing process and that garment size and shape needs to cater for this. However, she adds that altering the garments cut can have the effect of ageing the garment, making it less fashionable and limiting its marketing appeal to younger age groups and, more surprisingly, older age groups too. This is interesting notion, as she did not explicitly state if this is the view of the retailers or the customer but it does provide some explanation of why clothing for mature women does not always fit as well as it should. Fashion, Twigg (2015) states, is a system built on youthfulness. This thesis found this is indeed apparent when examining the literature in sections 2.2 and 2.4.

2.11 Applying 3D bodyscanning technology within clothing industry practice to improve garment fit

2.11.1 Sizing standards and the utilisation of anthropometrics

Hsu's (2011) study, using analysis of specific body ratios to create new sizing standards for mature women, reinforced the argument that older women's body shape change is very different from that of a younger woman. The work established critical variables - such as particular height and girth ratios - of the body - to classify different portions of the population. Central to Hsu's (2011) method was the use of factor analysis (akin to principal component analysis), a statistical method that helped reduce their anthropometric data, identify/categorise key variables and explain the linear relationships/correlations between them. However, prior to this stage of the analysis the sample data was reduced as a number of participants were discounted from the study if heights and weights deviated by $\pm 3\sigma$ from the calculated mean. This was termed by Hsu (2011) as abnormal data and seen as an outlier. It is not unusual for outlying data to seen as abnormal from a statistical perspective nor is it uncommon for it to be omitted from data sets, as there is the risk it could skew results. Nevertheless, the work set out to develop an accurate set of industrial standards to facilitate better apparel production for mature women using their anthropometric data. Body measurement standards based on anthropometric data according to Hsu (2011) are incorporated throughout the entire processes of apparel design and production. Yet Hsu's (2011) approach meant that some mature women, these outliers, are still not catered for within this standard thereby making it not a suitable standard for all mature women.

2.11.2 Anthropometrics and the garment fitting process

Conversely, Bye and LaBat's (2005) study of the US apparel fit process confirms that anthropometric practice is not considered as important or intrinsic to improving garment fit within the clothing industry. Their work entailed a survey and observation of industry clothing practitioners during a fit session. Their findings identified that fit models are measured sporadically, if at all, and garment measurements are discussed in isolation from the body. Istook's (2008) study of 3D bodyscanning technologies to improve garment fit comment that only tailors and haute couture houses utilised actual body measurements in the development and adjustment of their blocks and resulting garments. She also adds that apparel companies operating a mass production strategy operate under a system of garments made to a specific size and not garments made to fit. Often the standards on which these garment sizes were based are far removed from current anthropometric data, if based on anthropometric data at all.

Wren and Gill's (2010) later study which investigates clothing industry garment development practice explores how clothing practitioners development and amended the fit of their clothing offers. The study interviewed eight practitioners working for UK clothing retailers operating at the value to middle UK ready-to-wear market levels with some of the retailers catering directly for this study's demographic. The work found that each of the companies operated a mass production strategy as they catered for the High Street and concurred with Istook (2008) in that garment were made to a set size range (ready-to-wear garments) and not to fit specific individuals. These companies function under tight time constraints and as a result, pattern development practice is based on previous styled blocks and not on anthropometric data with additional ease allowances. Their work also indicates that these companies each used one fit model to assess the fit of the sample garment – a practice according to later work by Ernst & Koll (2014) which still occurs. Wren and Gill (2010) also learned that this fit model's anthropometric measurements were recorded infrequently if at all. These findings concur with Bye and LaBat's (2005) US study five years earlier showing that the practice of not regularly monitoring a fit model's dimensions was fairly widespread and, perhaps, could be seen as entrenched. Furthermore, Wren and Gill's (2010) work established that clothing companies sought to save time by omitting original pattern development. They did this through purchasing garments from their competitors with the aim of deconstructing and tracing around the garment portions to make pattern templates, something which is remarked upon in the text books of both Frings (2008) and Glock & Kunz (2005). This practice occurred with minimal changes to the original silhouette (Wren & Gill, 2010) in the belief that copying a garments shape and dimensions is also a means of copying competitors fit (Workman and Lentz, 2000). This practice signifies that body measurement, for these companies at least, is not an important consideration within the garment development process. This makes garment fit a recurring issue for all consumers and not just mature women.

2.11.3 Technology and consumer engagement within manufacturing paradigms

Hu's (2013) comparative paper concerned with manufacturing systems/strategies reflects on the evolving paradigms of manufacturing from mass production, through mass customisation and finally personalisation (a new and emerging paradigm). The work uses the automotive industry as a practical example although all three paradigms are or could be applied within the clothing industry's manufacturing structure. Hu (2013) argues that the paradigm of mass production has endured because it can yield high volume, low cost production, which is desirable for retailers as it is successful in terms of productivity and wealth for stakeholders within the company. However, Hu (2013) also states that this system has an innate weakness in that the consumer does not engage with the product development process. This implies that the process could give rise to products that are not designed around what a consumer actually needs or wants. He further argues that companies who engage with their target consumers requirements and facilitate consumer interaction within the design process are beginning to outperform those businesses who do not. Dong *et al* (2012) whose detailed study examined the paradigm of mass customisation within a clothing-manufacturing context further supports this idea. Dong *et al* (2012) states that the clothing industry is currently fiercely competitive, with competitors offering very similar services and products. They argue that allowing the consumer to engage with a part of the product development process gives the retailer a point of difference and a more exclusive product thereby weakening competition. Whilst there have been many studies exploring the implementation of the mass customisation paradigm within the garment industry (Kamali & Loker, 2002; Dong *et al*, 2012) most High Street clothing retailers use the mass production paradigm for their ready-wear-garments which does not provide the scope for such consumer engagement.

2.11.4 The clothing industry's current usage of 3D bodyscanning technology

Some retailers appear to understand that garment fit is an issue for all demographics and in an effort to understand the size and shape of their customer have participated in surveys, like that of SizeUK (2.6.1). The aim of the SizeUK survey was to gather information from potential consumers using 3D bodyscanning technology as it was perceived that it could help retailers improve the fit of their products through surveys of their target market's body dimensions (Ashdown and Loker, 2011). This anthropometric information is usually in the form of a list of quantitative body dimensions alongside visual data (King, 2014). Quantitative 3D bodyscanning data has attempted to be used for a number of clothing related applications. There are size prediction (Gribbin, 2014), body shape analysis (Gribbin, 2014; Lee *et al*, 2012), the development of mannequins for product development purposes (Bougourd, 2015), a review of company grade increments (Bye *et al,* 2008) and the development of virtual fit technology (Loker *et al*, 2008) for online shopping. It is possible for any of these applications to be used to improve clothing fit for a mature female demographic, but that is providing the hardware is calibrated correctly to take a clear image of the participant and the software contained landmark and measurement definitions that are appropriate for a mature demographic body morphology and clothing attribute requirements.

2.11.5 Size Prediction

Gribbin's (2014) reflective account of body shape's influence of garment size and, in turn, consumer choice, discusses how various 3D bodyscanning technologies can help the consumer engage with the retailer. Gribbin (2014) maintains that individuals who regularly experience garment-fitting issues would more readily engage with clothing retailers who attempted to provide garments that fit them. He substantiates this idea using examples of US retailers that have used 3D bodyscanning technology to gather large amounts of data in an effort to involve their customer base in correct garment size selection. His discussion focused around the Intellifit system, explaining that the hardware and software of this system worked by seeing through individuals garments to the skin surface using low intensity radio waves. Radio waves technology is different to the previously discussed scan capture technologies (2.7) in that the waves move through any clothing and bounce of the skin surface enabling the establishment of a point cloud image to facilitate body surface measurement extraction (Istook, 2008). Therefore, this type of bodyscanner would see through all clothing, lingerie included, unless masking algorithms were pre-programmed into the software to hide facial features and private body regions. A search of current literature indicates masking algorithms have been explored and developed for this type of technology (Laws *et al*, 2006) but masking parts of the data can change the scanned body surface so much that it no longer is an accurate representation of the person who has been scanned. This, perhaps, explained why there appeared no such research specifically for the clothing industry, as an accurate representation of the skin surface was necessary to first landmark and then extract measurements from. Gribbin (2014) acknowledged that the system can see through clothing but did not explicitly discuss any efforts to protect participant identity and modesty, nor did he confirm if the participant could see their scan data, something that may alarm potential customers if they were aware of this.

The Intellifit technology was placed within shopping centres and stores to gather consumer data (Gribbin, 2014) which was both numerical, visual and written. The software compared participant body dimensions to a list of retailers garment dimensions to select a suitable size code, depending on where the participant would like to shop (Polvinen, 2012). Intellifit technology is a novel approach but scrutiny of its process reveals it facilitates passive engagement, as it does not allow the consumer to challenge/validate the accuracy of the data it takes nor does it enable the consumer to have a voice regarding the fit of the suggested garments. Gribbin (2014) omits any discussion around the measurement extraction parameters and body landmarks that are within the software, making it difficult for the reader to ascertain where the key body measurement for clothing were extracted or if the extraction sites were appropriate for a mature demographics' body morphology. Without this information it is difficult to confirm if the Intellifit scanner 3D can reliably provide size code data for a mature female demographic.

2.11.6 Mannequin development

3D bodyscanning can facilitate the opportunity to custom-make stands using the extracted skin surface data thereby providing a more realistic shape (Gribbin, 2014; Bougourd, 2015). Bougourd's (2015) case study explored how 3D bodyscanning data, more specifically the SizeUK data set, can be applied to the garment development process for mature UK women. Her work established that the scan data from this survey was used by a prominent UK retailer to generate a clothing mannequin. This mannequin was subsequently used for its garment development process. She implies that the mannequin displayed a more mature female size and shape although the images provided look somewhat generic (*Figure 2-27*). This work is valuable in that it could educate clothing practitioners to body shape change using a visual means and, presumably, more authentic body morphology. Seeing and being able to touch the topography of the body can help with developing accurate pattern geometry. Problems however arise when the shape provided becomes an amalgamation of lots of data into one body form, which is the case in Bougourd's (2015) study. The dimensions and shape of the stand were standardised using population averages of key body length and girth dimensions. This means that anyone who deviates away from the average (the outliers) would find that garments developed and fitted using this form would have fit issues for them. It also indicates that using an average of any population's dimensional data can result in a garment that fits no one in particular.

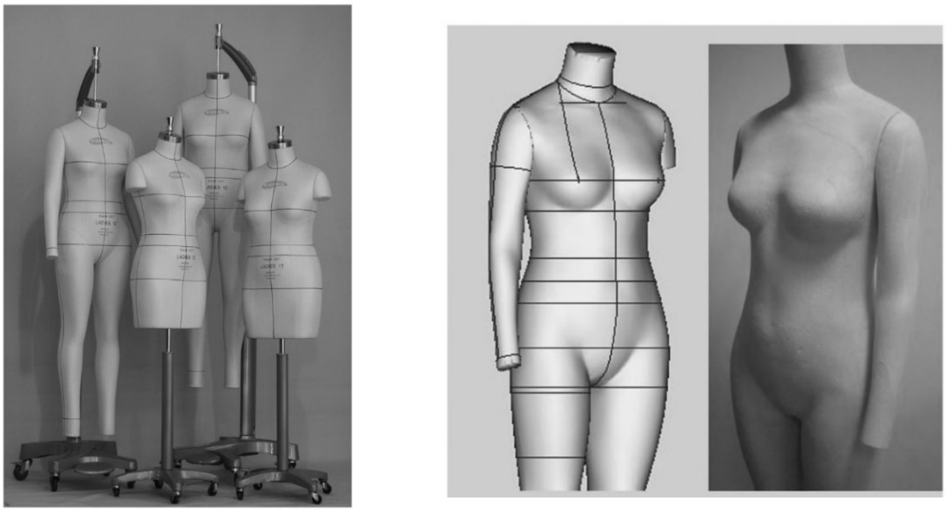


Figure 2-27 Mature body shape mannequin developed using Size UK data source: Bougourd (2015)

3D body scanning technology can help retailers improve the fit of their products through surveys of their target market's body dimensions, according to Ashdown and Loker (2011). However, to date, mainly educational institutions (Aldrich, 2008) have used 3D bodyscanning within the UK as a survey tool for the clothing industry (King, 2014). As a result, research into its application and further integration within the product development process is necessary (Gill *et al*, 2014b), particularly for the mature woman as the 2011 UK census indicates that the UK has an ageing population with the largest portion of elderly citizens being in the 55-64 brackets and with women out-numbering men (National Statistics, 2013).

2.11.7 Bodyscanning and virtual 'try on' technologies

In an attempt to address sizing and fit issues for online retailing, computer software companies such as Fitsme.com, Metail, and Styku have developed 3D software technology, which allows the customer to try on the garments before they buy them (Kim & Forsyth, 2008). Fitsme and Metail offer very similar products in that a customer can input their body measurements and the software converts an existing avatar's virtual body surface to those dimensions, which then allows garments to be fitted on the avatar so the customer can view the garment's fit (Metail.com, 2013; Fits.me, 2013). Virtual fit technology seems a step in the right direction, in terms of using individual's body measurements to determine the right size of garment, but this form of the technology has limitations. The first, and most obvious, limitation concerns the distance between the required girth measurements, for example the depth between the bust point and the waistline. The software does not have a facility to input depth measurements such as this, only girth measurements, and so it could be assumed that these depth distances are predetermined/written within the software algorithms and as such are fixed. Predetermined distances such as bust point to waistline are not the same for all women and can vary greatly when comparing a young women's bust position to that of a mature women as illustrated in the images provided in Veitch's (2014) paper *Figure 2-25* and *Figure 2-26*. Therefore, without the facility to input depth measurements the resulting avatar will not produce an accurate body model on which to try on the clothes making the process a pointless exercise and an unhappy customer.

Bodyscanning technology, when linked to other systems or processes, could provide alternative applications to that of a survey tool. Virtual fit technology using 3D bodyscanning systems are being developed, although access to the consumer is not yet widely available (Loker *et al,* 2008). Measurements such as Height/depth measurements are necessary to provide an avatar that more accurately reflected the segment lengths of the individual consumer's body (2.11.7), whereas most virtual try on technologies only ask for girth measurements. However, it is evident that 3D bodyscanning technology when used with other applications for a mature demographic needs further research particularly regarding the definitions for difficult to locate landmarks such as the waist.

2.12 Theoretical framework

2.12.1 The key themes and theories with in: current knowledge regarding age-related body morphology change and 3D bodyscanning technology

Age-related morphological change

- Mature women lose height due to changes in posture (Ashdown and Na, 2008; Woodson and Horridge, 1997; Cutler et al, 1993; Sorkin et al, 1999)
- Mature women gain weight due to changes in hormone levels and their waist-line becomes less distinct (Perissonotto et al, 2002; Buffa et al, 2005; Ley et al, 1992)
- Mature women are more likely to manifest postural and physical asymmetry (Blaszczczyk and Michalski, 2006)
- Mature women are more likely to display a rectangular body shape which again has a less discernible waist shape (Goldsberry et al, 1996; Lee et al, 2007)

Three dimensional bodyscanning landmarking practice limitations

- Three dimensional bodyscanning can be less accurate for individuals with non-standard body morphologies (Sims et al, 2011)
- There needs to be flexibility in landmarking definitions for different body types (Han and Nam, 2011)
- Anatomical waist definitions are not suitable for clothing development (Veitch, 2014)
- Landmarks cannot be located by visual analysis alone (Kouchi and Mochimaru, 2011)
- Manual landmarking have been used alongside non-contact methods but this requires pre-landmarking the participant (Robinette and Daanen, 2003)

2.12.2 The key themes and theories (in grey boxes) with identified knowledge gaps (clear boxes)

Mature women and 3D bodyscanning technology

- Mature women have modesty issues when asked to remove their clothing for anthropometric measurement (Woodson & Horridge; Patterson and Warden, 1983; Goldsberry *et al,* 1996)
- The 3D bodyscanning process requires that participants wear minimal clothing (BS EN ISO 20685:2010)
- Scan images can be difficult for some women to view (Domina *et al,* 2007)
- Mature women and women with high BMI scores are sensitive about seeing their scan image (Grogan *et al,* 2015; Lee *et al,* 2011)

3D bodyscanning practice is based on standard anthropometric benchmarks

- Clear scan capture relies on upright posture (McKinnon and Istook, 2002; Sims *et al,* 2011)
- The TC² 3D bodyscanner uses non-contact anthropometric practice to position landmarks and extract body measurement dimensions (King, 2014)
- The landmark and measurement definitions used by the 3D bodyscanner are benchmarked against manual landmark and measurement definitions (Shin and Istook, 2006; cordis.europa.eu, 2007)
- The TC² 3D bodyscanner uses template matching which utilises a standard body morphology as its template. This template is not effective for individuals who no longer exhibit a standard body morphology (Sims *et al,* 2011)
- Knowledge of 3D bodyscanning application is scant (Gill *et al,* 2014b)

2.12.3 Proposition statements (in grey boxes) the gaps in the knowledge base identified and synthesised by this thesis (clear boxes)

Manual anthropometric practice requires adaptation to cater for a mature female's body morphology and concerns over privacy

- Manual anthropometric practice is based on a standard upright, youthful body morphology which is not applicable to some mature women (2.2.1)
- Manual anthropometric practice in the past has had to adapt its equipment and methods to cater for women aged 55+ (2.5.1)

Pattern construction guidance requires adaptation to develop a bodice block for mature women

- Pattern construction guidance uses similar body morphologies and its measurement definitions are benchmarked by traditional anthropometric practice (2.4), this means a non-standard body morphology is unfamiliar to those using the guidance.
- Pattern construction guidance is variable in terms of its clarity (2.4) meaning those with limited anthropometric knowledge would struggle to apply it to a mature participant's body morphology.
- Pattern amendment guidance is targeted at individuals perceived to have body faults or flaws (2.4.1) which has negative connotations. It is often seen as an 'add on' to pattern construction text and can be found towards the rear of a publication.
- Pattern and garment fit is improved if the position of the measurements taken is correct (2.4).

Exploration of the 3D bodyscanner needs to be done through the lens of a clothing practitioner to make it more accessible to the clothing industry

- Details of how bodyscanning data is validated are limited (2.6.3)
- Current studies which seek to develop applications for body scanning within the clothing industry use knowledge that is outside of a clothing practitioner's skills set (2.8.2)

Participant engagement to validate landmark placement within the non-contact anthropometric process

- Mature women have firm ideas of what they like to wear and how they want clothes to fit (2.10.1)
- Mature women use clothing as a means of body correction (2.10.1) to give them what they perceived to be a more pleasing body shape such as a defined waist.
- The waist is difficult to locate without using palpation and more so on individuals who have excess fat deposition around the abdomen (2.3.4)
- Individuals can indicate with a degree of accuracy where particular landmarks are on their body using their proprioceptive knowledge (2.3.5).
- Some retailers provide facilities for customers to measure themselves to check their key body dimensions against the key garment dimensions (2.11.5). This indicates they trust customers to undertaken this process.

3 Methodology to establish the viability of 3D body scanning as a tool to improve garment fit within the clothing product development process for mature females (aged 55+)

3.1 Introduction

This methodology chapter opens with a process map of the research design (*Figure 3-1*) accompanied by a tabulated guide (*Table 3-2*) providing the purpose of each activity and the tasks required to undertake each step. The methodology for this thesis was not entirely linier and it was thought the best way to present the research design was to provide a visual so the viewer can see how each objective was undertaken and completed. The methodology chapter then moves on to provide a more detailed rationale and description of the research design beginning with the key literature sources that formed the basis of the theoretical framework as shown in section 2.12. This framework guided the research question throughout and flagged areas that needed attention which were for example age related body shape/size change. The key literature sources cited within the theoretical framework also provided a rationale for the choice of some of the methods and choice of philosophical paradigm. Key themes from the theoretical framework were outlined to convey, at first a set of propositions statements, and then a null and alternative hypothesis statement. The methodology chapter then moves on to discuss the practical details of the research such as sampling, data collection tools and most appropriate analysis procedures. The order in which these practicalities are discussed where possible in the same order as the Objectives outlined in section 1.3.1.

3.2 Model of the research design and supporting table

A process map was developed in Microsoft Visio (*Figure 3-1*) to illustrate how the different components of this research fitted together and structured the selection of methodologies and the supporting tools. A process map can be defined as a business-planning tool that is used to visually illustrate a process, a procedure, or how a series of processes and procedures fit together. It can be supported, where required, with a table of activity steps that add additional levels of detail to the process map itself, which this thesis did.

3.2.1 Key

Business Process Modelling has defined standards for the icons used in a process map as shown in the key of *Figure 3-1*. For the purposes of this research a standardised set of icons where used to explain the methods and a key has been provided. To explicate this further the icon usage has been expanded on below in *Table 3-1*.

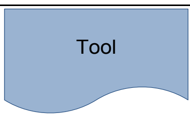
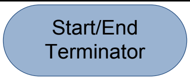
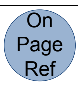
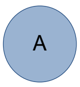
 This icon represents standard process.	 This icon represents a predefined process that was developed by this researcher in collaboration with other academics.
 This icon represents a new process developed to facilitate this research.	 This icon represents data being produced.
 This icon has been used to represent the development and deployment of documents used as tools to facilitate this research.	 This icon is used as the starting and end point of a process flow.
 This icon represents the outputs from processes and the input into other processes and tools as an 'on page reference' symbol.	

Table 3-1 an explanation of the symbols used in the process map of the research

3.2.2 On Page Reference detail

The 'on page reference' symbol has been used to describe specific outputs and inputs on this process map. To aid understanding, the individual 'on page references' work as follows:



On Page Reference A: This symbol details how the literature review informed the production of tools for the non-contact anthropometric survey.

B On Page Reference B: This symbol details how the literature review informed the need for a survey of retailers’ measurement guidance.

C On Page Reference C: This symbol details how the theoretical framework informed the need for a survey of anthropometric surveys and 3D bodyscanning technology, which in turn influenced the development of the conceptual model.

D On Page Reference D: This symbol details how the theoretical framework informed the selection of the pattern methodology for pattern generation.

E On Page Reference E: This symbol details how the how the feedback from the questionnaire tool contributed to the development of the fit pro forma.

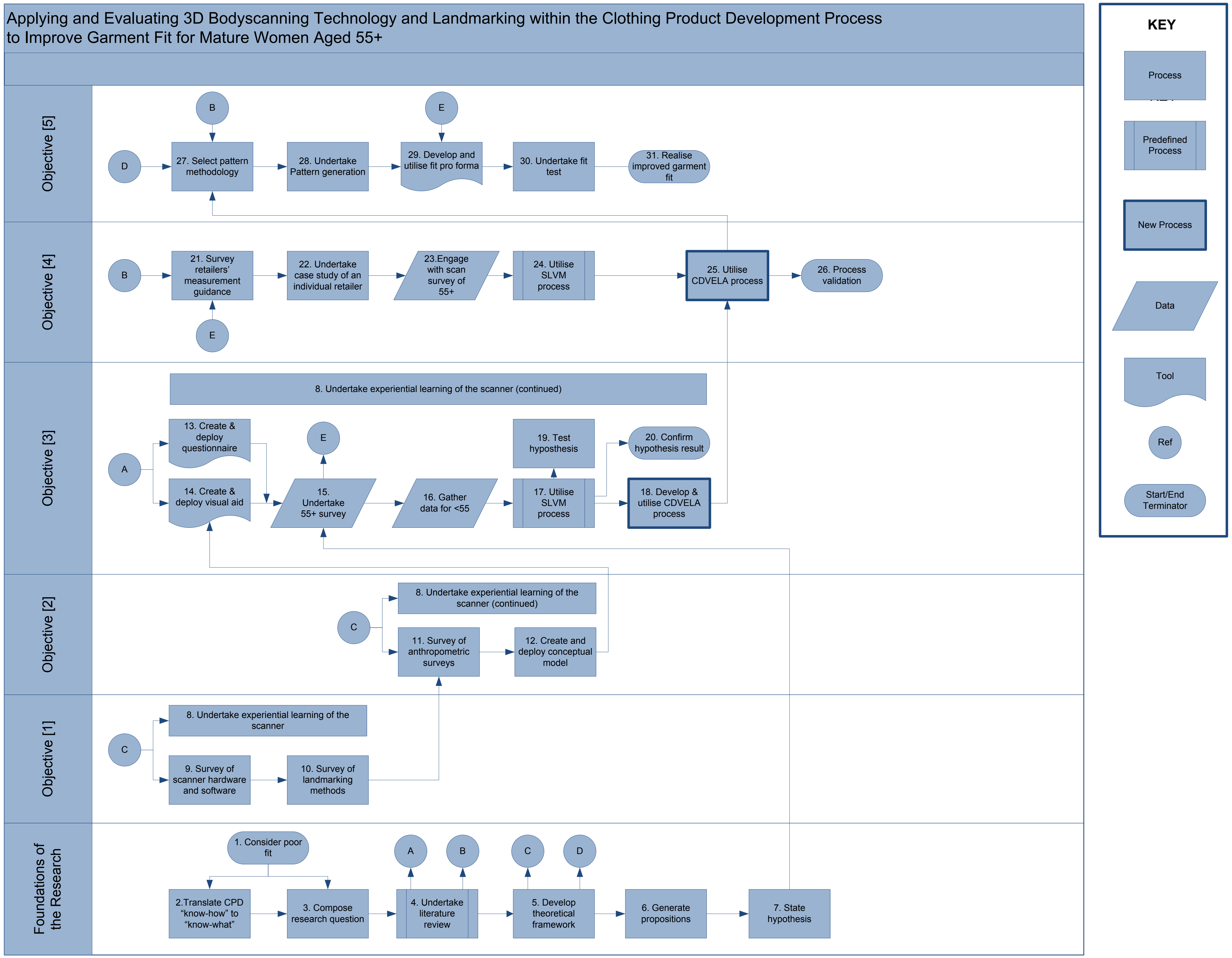


Figure 3-1 The process map of the development of the research question and the methodologies used by this thesis

<table>
<tr><th>ACTIVITY No.</th><th>ACTIVITY STEP DESCRIPTION</th></tr>
<tr><td>Activity 1</td><td>Consider poor fit
Purpose: To review the causes of poor fit with input from industry clothing practitioners, consumers, and clothing academics, with particular reference to, “The Garment Fitting Process: the inter-related issues and problems that impact upon clothing fit and how industry personnel and procedures address poor fit” by Paula Wren (unpublished MSc thesis, 2009)

Steps undertaken:

Input received from clothing practitioners. This included but was not limited to:
Interviews with professional clothing designers, pattern cutters and garment technologists
Input received from clothing academics. This included but was not limited to:
“Industry Fit Practices and Issues that Impact on Good Garment Fit” (see Wren & Gill, 2010)
Input received from consumers. This included but was not limited to:
Observations of customer activity in store to inform product development
Informal customer feedback collected in store to inform product development
Feedback from the 55+ female demographic revealed high levels of dissatisfaction with garment fit
</td></tr>
<tr><td>Activity 2</td><td>Translate CPD practice to theory
Purpose: To translate clothing product development (CDP) tacitly-held knowledge of industry practices into explicitly articulated theoretical knowledge as evidenced in the author’s MSc thesis, “The Garment Fitting Process: the inter-related issues and problems that impact upon clothing fit and how industry personnel and procedures address poor fit” by Paula Wren (unpublished Master’s thesis, 2009).

Steps undertaken:

Worked for over 18 years as a professional clothing practitioner in CPD acquiring a breadth of experience
Reflected on personal practice to explicate tacit practical knowledge during the course of studying for the MSc
Reviewed the academic literature to identify the issues of poor fit during the course of studying for the MSc
Identified that some solutions proffered included technologies not accessible to CPD practitioners
Identified that some solutions proffered required skillsets extrinsic to the CPD practitioners existing skillset
Interviewed 8 professional clothing practitioners as part of the author’s MSc dissertation
Identified commonalities amongst skillsets in the area of garment fit
</td></tr>
</table>

ACTIVITY No.	ACTIVITY STEP DESCRIPTION
Activity 3	**Compose research question** **Purpose:** To compose the research question following the review of poor fit and the explication of tacitly held industry practices. Steps undertaken: • Integrated the knowledge of poor fit for the 55+ female demographic with the explicitly articulated theoretical knowledge of the practices of CPD professionals to inform a research question • Explored 3D bodyscanning technology to investigate whether it could contribute to the solution of poor fit to inform a research question • Developed the working title of the research question

Activity 4	**Undertake literature review**
	Purpose: To review the existing academic and industry knowledgebase with particular focus on garments for the over 55-years female demographic, anthropometric practices (manual through to non-contact), gerontology, the application of 3D bodyscanning technologies to clothing, and pattern development methodologies.
	
	Steps undertaken:
	• Examined the current literature surrounding the themes and accompanying theories of:
	  o Generic anthropometric practice
	  o Female age-related body morphological change,
	  o Body measurement guidance and clothing pattern development
	  o Anthropometric studies for mature women,
	  o Anthropometric surveys using 3D bodyscanning technology,
	  o Non-contact landmarking methods
	  o Mature women's perceptions of 3D bodyscanning technology
	  o Mature women's understanding and requirements of clothing,
	  o Clothing retailers' view of female ageing and their clothing offer
	  o Current applications of 3D bodyscanning technology for the clothing industry
	• Informed the development of a questionnaire and visual aid (as deployed in **Objective [3]**)
	• Informed the need to survey retailers' measurement guidance (as undertaken in **Objective [4]**)
	• Informed the selection of pattern methodology (as undertaken in **Objective [5]**)

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 5	**Develop theoretical framework**
	
	Purpose: To synthesise the critically reviewed academic and industry knowledgebase analysed in the literature review to form a theoretical framework in order to introduce, describe and support the theory that justifies the research question.
	Steps undertaken:
	• Isolated key themes, sources and theories from the literature review
	• Identified pertinent critical gaps in the existing knowledgebase
	• Synthesised the key themes, sources and theories and applied to the pertinent critical gaps to develop the theoretical framework
	• Informed the necessity of experiential learning of the 3D bodyscanner hardware and software (as undertaken in **Objective [2]**)
	• Informed the requirement to survey:
	    ○ Landmarking surveys (as undertaken in **Objective [1]**)
	    ○ 3D bodyscanning hardware and software (as undertaken in **Objective [1]**)
	    ○ Anthropometric surveys (as undertaken in **Objective [2]**)
	• Informed the selection of pattern methodology (as undertaken in **Objective [5]**)

Activity 6	**Generate propositions**
	Purpose: To generate proposition statements to illustrate associations amongst concepts and to highlight the logical links in order to contribute to the generation of a hypothesis.
	
	Steps undertaken:
	• Composed a series of proposition statements. These were:
	    ○ **Proposition Statement 1:** 3D bodyscanning technology is not 100% accurate in its landmarking capability, particularly when applied to non-standard body morphologies
	    ○ **Proposition Statement 2:** Mature women's body size and shape undergoes age-related changes which varies person to person, and can move the size and shape away from what is considered standard
	    ○ **Proposition Statement 3:** Mature women have particular aesthetic and comfort related clothing requirements and can use these to inform clothing fit
	    ○ **Proposition Statement 4:** Mature women have unique proprioceptive knowledge of their body
	    ○ **Proposition Statement 5:** Mature women's proprioceptive knowledge can be used to improve the landmark positioning process within 3D bodyscanning technology
	    ○ **Proposition Statement 6:** Technician skilled in anthropometrics and 3D bodyscanning technology can interface with the system to evaluate and improve its landmarking accuracy

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 7	**State hypothesis**
	Purpose: To articulate an explicit statement that contains both dependant and independent variables that will be tested. This is the null hypothesis and the alternative hypothesis. The null hypothesis will then be tested by the relevant quantitative methodologies.
	
	Steps undertaken:
	• Composed the null hypothesis. This was articulated as follows:
	    o The independent variable of age-related body morphology change has no effect on the precision on the dependent variable, automatic non-contact landmarking, and the subsequent body measurements, and therefore these landmarks and ensuing body measurements do not require their accuracy validating.
	• Composed the alternative hypothesis. This was articulated as follows:
	    o The independent variable of age-related body morphology change has an effect on the precision on the dependent variable, automatic non-contact landmarking, and the subsequent body measurements and therefore, these landmarks and ensuing body measurements do require their accuracy validating.
	
	NOTE: The appropriate tests, involving both descriptive and inferential statistics, were selected to test the null hypothesis as part of **Objective [3]** (see **Activity Step 19**).

Activity 8	**Undertake experiential learning of the scanner** **Purpose:** To undertake experiential learning of the scanner through utilisation of the learning opportunities afforded through the role of Senior Lecturer in Fashion Design Technology at the Department of Apparel and in the course of this research project. Steps undertaken: • Reviewed all accompanying guides related to the TC^2 3D bodyscanner (Models NX16 and KX16) • Participated in scanning projects for undergraduate programmes • Collaborated on scanning projects with other academics (see Gill *et al*, 2014a and Gill *et al*, 2014b) • Gathered data by scanning the 55+ female demographic (as undertaken in Objective [3] Activity 15) o Modified gathered scan data **NOTE:** The ongoing nature of experiential learning is represented herein as part of **Objective [1]** (**Activity Steps 9 and 10**), **Objective [2]** (**Activity Steps 11 and 12**) and **Objective [3]** (**Activity Steps 13 to 20**).

<table>
<tr><th>ACTIVITY No.</th><th>ACTIVITY STEP DESCRIPTION</th></tr>
<tr><td>Activity 9</td><td>Survey of scanner hardware and software
Purpose: To undertake a survey of proprietary 3D-bodyscanning hardware and software of in order to develop an understanding of how the hardware and software operate together in the scanning process.
Steps undertaken:
Reviewed proprietary promotional material. This included 13 companies in total including:
3D Digital Corporation
ABW
Arius 3D
Breuckmann
Cyberware
Digibot
TC^2
Vitus
Captured information relating to:
Size and purpose of scanner
Software and hardware configuration
Surveys in which the technology had been used
Light source technology used
Limitations
Tabulated the details of using Excel</td></tr>
<tr><td>Activity 10</td><td>Survey of landmarking methods
Purpose: To undertake a survey of existing academic landmarking methods in order to determine whether these methods could be readily adopted by professional non-academic clothing practitioners.

Steps undertaken:
Reviewed the methods and findings of previous academic studies whose focus had been developing novel landmarking methods utilising both traditional and non-contact landmarking practice
Populated a table of landmarking methods using Excel
Only studies relevant to clothing generation were included
Highlight strong and weak relationships between manual and non-contact methods in for each novel landmarking method found</td></tr>
</table>

<table>
<tr><th>ACTIVITY No.</th><th>ACTIVITY STEP DESCRIPTION</th></tr>
<tr><td>Activity 11</td><td>Survey of anthropometric surveys
Purpose: To undertake a survey of existing anthropometric surveys in order to establish which methodologies were used and whether any previous surveys had targeted the 55+ female demographic for data collection.
Steps undertaken:
Identified and reviewed surveys that were not specific to the clothing industry
Identified and reviewed a number of international surveys that were specific to the clothing industry
Compiled a table of recent international anthropometric practice. Data was sorted into:
Survey purpose
Sample size
Type and number of body measurements taken
Whether the survey was published
Only studies relevant to clothing generation were included</td></tr>
<tr><td>Activity 12</td><td>Create and deploy the conceptual model
Purpose: To build a new conceptual model by assembling the different approaches to human anthropometric measurement and to present their relational links in a visual format.

Steps undertaken:
Developed the conceptual model by assembling the different approaches to human anthropometric measurement
Deconstructed the landmarking process into:
The conditions/environment of the landmarking process
The stages of the landmarking process
The tasks undertaken by technicians within the landmarking process
The tasks undertaken by the hardware and the software within the landmarking process
Illustrated the conceptual model using Power Point</td></tr>
</table>

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 13	**Create and deploy questionnaire**
	Purpose: To create and deploy a questionnaire as part of a mixed methodological approach in order to allow participants to voice their concerns regarding garment fit and to provide details of preferred retailer in regards to better fit.
	
	Steps undertaken:
	• Created the questionnaire
	    o Reviewed findings from literature concerning body shape change to inform questions
	    o Reviewed the measurements required for pattern development to inform questions
	    o Reviewed reported fit issues in fit alteration literature to inform questions
	    o Drafted questions
	• Deployed the questionnaire to undertake a survey of the 55+ female demographic

Activity 14	**Create and deploy visual aid**
	Purpose: To create and deploy a visual aid as part of a mixed methodological approach in order to allow participants to engage with the evaluation of scan data by specifying their waist landmark position preference for clothing and where they felt their natural waist was located.
	
	Steps include:
	• Developed a visual aid to facilitate the collection of subjective data provided by the participants of the questionnaire
	    o Anonymised a scan image of the 55+ female demographic to create the visual aid via Adobe illustrator
	    o Identified 4 different placements of the waist from the a review of the literature
	    o Added the placements of the waist at the 4 different intervals along the torso of the anonymised scan image
	• Deployed the visual aid to undertake a survey of the 55+ female demographic

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 15	**Undertake 55+ survey**
	Purpose: To undertake an anthropometric survey of the 55+ female demographic using 3D bodyscanning technology to collect quantitative body measurement data**.**
	
	Steps undertaken:
	• Created 2 x posters to recruit participants for the anthropometric survey
	    o One was used for recruitment in Manchester
	    o One was used for recruitment in Nottingham
	• Recruited participants using 4 different sampling strategies
	• Undertook the anthropometric survey using TC^2 NX16 and the KX16 3D bodyscanning models
	• Used a standard Measurement Extraction Parameter (MEP) developed by Manchester Metropolitan University (MMU)
	
	NOTE: Feedback received from the questionnaires used during the survey process gave details of participants' preferred retailer outlets. Therefore, these retailers were included in a survey of retailer measurement guidance as seen in **Objective [4]** (see **Activity Step 21**).

Activity 16	**Gather scan data of <55 (18-25 and 35-45 year old women)**
	Purpose: To gather scan data of the under 55-year old female demographic (18-25 and 35-45 year old women)
	In order to test and examine the null hypothesis.
	
	Steps undertaken:
	• Accessed existing scan data from the MMU pool of scan data
	    o 38 scans for the 35-45-year old female demographic age cluster were selected as this was the total sum available
	    o A random sample of 66 scans for the 18-25 female demographic age cluster were selected from a total of 1584

ACTIVITY No.	ACTIVITY STEP DESCRIPTION
Activity 17	**Utilise SLVM process** **Purpose:** To check the scans images were clear and free from occlusions the Scan Landmark Validation and Modification (SLVM) was utilised. If landmark error was detected the SLVM process was used to reposition landmarks during this process. Steps undertaken: • Reviewed all unmodified scan images were qualitatively evaluated for viability and modified, if required • Checked all landmarks from the chin point to the ankle as part of the SLVM process • Renamed the newly modified scan with scan number and a code indicating where the modification had taken place • Rejected scans with significant occluded areas (gaps of data in the scans). • Listed all modifications and area of modification for each age cluster into an Excel spreadsheet • Saved unmodified and modified scans in separate folders • Batch processed both unmodified and modified scans an Excel file • Colour-coded the modified and unmodified pairs of scan • Reduced the batch processed measurements to only torso measurements • Used descriptive statistics to calculate the proportion of landmark errors within each age cluster

Activity 18	**Develop & utilise CDVELA process**
	Purpose: To develop a process that explores possible causes of landmarking/body measurement error, as well as providing the opportunity for participant engagement within the non-contact anthropometric process, the Comparison of Demographics and the Variables which can Effect Landmarking Accuracy (CDVELA) process was created. The CDVELA process was then deployed.
	Steps undertaken:
	• Applied the CDVELA process to the scan image
	• Counted each landmark modification for each participant within each age cluster
	• Calculated the BMI for each participant within each age cluster
	• Calculated the body shape for each participant within each age cluster
	• Undertook descriptive statistics to show the proportions per age cluster of:
	    o Average age
	    o Average BMI
	    o Average body shape
	• Illustrated the percentages of these averages and compared between the age clusters in a chart using Excel
	• Modified the waist landmark for the 55+ age cluster according to the feedback from the visual aid
	• Subtracted modified waist girth from unmodified waist girth to determine the ‘value difference’ between both measurements
	• Illustrated this difference in a chart format using Excel
	• Calculated the coefficient variance percentage using Excel

<table>
<tr><th>ACTIVITY No.</th><th>ACTIVITY STEP DESCRIPTION</th></tr>
<tr><td>Activity 19</td><td>Test null hypothesis
Purpose: To test the null hypothesis using a one-tailed t-test assuming unequal variances and an alpha value of 0.05.

Steps undertaken:

Reviewed the descriptive statistics which showed the proportion of landmark errors within each age cluster
Collated only scans which had a landmark modification into a new Excel workbook
Isolated the unmodified and modified scan measurement data into a new Excel spread sheet for:
Crotch point to floor
Bust girth
Armhole width
Armhole depth
Subtracted the modified measurement from the unmodified measurement to give the value difference measurement
Collated the value difference measurements for the 18-45 female demographic sample into a new Excel spread sheet
Collated the value difference measurements for the 55+ female demographic sample into a new Excel spread sheet
Ran a one-tailed t-test comparing the 55+ data against the 18-45 using Excel
Generated a p value
</td></tr>
<tr><td>Activity 20</td><td>Confirm/reject null hypothesis
Purpose: To confirm or reject the null hypothesis the p value must be interpreted against alpha value of 0.05.

Steps undertaken:

Tabulated the results of the one-tailed t-test
Interpreted the p value to reject or confirm the null hypothesis
</td></tr>
</table>

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 21	**Survey of retailers' measurement guidance**
	Purpose: To undertake a survey of retailers' measurement guidance in order to gain an insight into the quality of provision of anthropometric guidance provided by High Street retailers who directly target the 55+ female demographic as customers.
	
	Steps undertaken:
	• Captured details of preferred retailers for the 55+ female demographic during the anthropometric survey
	  ○ A purposive sample of 24 UK women's clothing retailers were chosen on the basis that the retailers' target customer was a mature woman
	• Created a list of criteria order to appropriately expand the list of preferred retailers. The criteria included:
	  ○ Retailers whose size charts did not contain small sizes such as a size 4 or 6
	  ○ Retailers who used mature models to promote their garments
	  ○ Retailers whose garments were styled or accessorised in a more classic manner
	• Added a further 33 retailers to the preferred retailer list resulting in a total of 57 retailers under review
	• Collected measurement guidance, when available, from online store sites of these 57 retailers
	  ○ This data was reduced and tabulated
	• Open-coded the measurement description and visual aid using a template analysis approach in Excel

Activity 22	**Undertake a case study of an individual retailer**
	Purpose: To undertake a case study on an individual retailer in order to gather primary data of the company practices of a large UK High Street clothing retailer using 3D bodyscanning technology. The retailer was identified as a preferred retailer by the 55+ female demographic in the questionnaire deployed in **Objective [3]** (**Activity Step 13**).
	
	Steps undertaken:
	• Attended meetings between professional clothing practitioners and clothing academics to discuss the company's requirements of the scanner.
	• Determined the nature of the data from the case study
	  ○ Documented the minutes of meetings
	  ○ Documented email correspondence
	• Collated and saved digital copies of company artefacts prior to the anthropometric 3D bodyscanning survey
	• Engaged with the retailer's anthropometric 3D bodyscanning survey

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 23	**Engage with scan survey of 55+**
	Purpose: To engage with the retailer's 3D bodyscanning anthropometric scan survey in order to observe and document how they utilise the scanner.
	
	Steps undertaken:
	• Provided guidance on the application of the scanner for anthropometric survey purposes
	  o Answered queries relating to the scanner Measurement Extraction Parameters (MEPs)
	  o Provided guidance regarding the development of an accompanying questionnaire
	  o Partook in a promotional video of the scanning process as part of the anthropometric scanning event recruitment process
	• Attended the event and participated in the 3D bodyscanning anthropometric scan survey
	  o Scanned participants
	  o Documented participants' measurements for use with the retailer's Metail technology
	  o Recorded observations of the event via field notes
	• Communicated post-survey with the retailer

Activity 24	**Utilise SLVM process**
	Purpose: To gain insight into how a typical UK High street company utilises scanning technology in their business and to evaluate the scan data using the SLVM process.
	
	Steps undertaken:
	• Created an Excel workbook to record modifications for each participants' scan
	• Checked all landmarks
	  o Landmarks ranged from the chin point to the ankles
	• Corrected landmarking errors, where possible, and renamed the newly modified scan
	  o Coded the newly renamed scans to indicate where the modification had taken place
	  o Saved scans with significant occluded areas that resulted in gaps of data in a separate file in readiness for the CDVELA process
	  o Saved unmodified and modified scans in separate folders in readiness for the CDVELA process

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 25	**Utilise CDVELA process**
	Purpose: To utilise the CDVELA process in order to feedback the 3D bodyscanning data from the anthropometric scanning event to the case study retailer.
	
	Steps undertaken:
	• Included only scans that had been through the SLVM process
	  ○ Calculated average age
	  ○ Calculated the average body shape
	  ○ Calculated the average bust, waist, high and low hips dimensions
	• Contributed to a report that was feedback to the retailer
	  ○ Provided details of participants' scan error and correlated the error with body shape and/or body posture

Activity 26	**Process validation**
	Purpose: To confirm the CDVELA process can be used in an industrial environment
	
	Steps undertaken:
	• Discussed the content of the report with the company
	  ○ Recorded any issues regarding the usage of the CDVELA process for the company's anthropometric scanning event
	  ○ Amended the CDVELA if needed for future use

ACTIVITY No.	ACTIVITY STEP DESCRIPTION
Activity 27	**Select pattern method** **Purpose:** To choose a suitable pattern methodology which effectively utilises the scanner's direct body surface measurements. To select appropriate scans from each of the age clusters for pattern development. Steps undertaken: • Surveyed existing pattern methodologies within the literature review • Selected a method which utilises mostly direct body measurements • Identified that this method facilitates depth measurements from the side neck point to the bust prominence and bust prominence to the waist as the literature showed age-related body change can mean the bust girth increases and the bust prominence is lower on the torso • Developed a criteria which enables selection of suitable scan data for pattern development Regrouped the entire sample based on height ○ Selected a participant from each age cluster who shares a similar height ○ From this selected participants who had have had two or more modifications of the landmarks ○ Confirmed that this reduced the sample to 9 participants requiring 18 patterns to be drafted • Copy the unmodified and modified scan dimensions into a new Excel workbook in readiness for bodice pattern preparation and manual drafting **NOTE:** The literature review examined different pattern methods as seen in the **Formulation of the Research** section (see **Activity Step 4**). The theoretical framework outlined the issues of age-related morphological change and pattern construction limitations and knowledge of this link identified the most appropriate best pattern construction method for this research as seen in (see **Activity Step 5**).

ACTIVITY No.	ACTIVITY STEP DESCRIPTION

Activity 28	**Undertake pattern generation**
	Purpose: To compare scan measurements definitions for a bodice against Beazley and Bond's (2003) bodice measurement definitions. To visualise the different pattern geometry of unmodified and modified scan measurement data. To produce patterns to facilitated toile development.
	
	Steps undertaken:
	• Compared the definitions of Beazley and Bonds pattern measurements against similar ones from the 03_4cm_tolerance MEP file
	  ○ Identified measurements which are not similar in their definition or that need combined measurements
	  ○ With guidance from a senior Manchester University academic wrote a new MEP for the TC^2 software for a Beazley and Bond's (2003) bodice block including any new measurements which share the same or similar definitions to that of Beazley and Bonds (2003) method. Termed it the 03-MMU-V5-SG-Scyedepth.mep
	• Batch processed both unmodified and modified scans of the nine women using the new MEP and placed the resulting body measurements into a new Excel spreadsheet
	• Used manual drafting techniques to draft each set of patterns side by side on the same sheet of paper
	• Completed drafting and trued the darts, the neck and the armholes
	• Presented the patterns, the batch processed measurements and the pattern method to a senior Manchester Metropolitan University academic for scrutiny and feedback of each set of patterns
	• Recorded the academics feedback in a table
	• Digitised the patterns into the Gerber Pattern Design System and named each pattern with the participant scan number appended by either U or M to indicate unmodified and modified data used
	• Added seam allowances to each pattern for seams and a closure
	• Saved the patterns to a digital file
	• Plotted off the patterns with seam allowance
	• Cut the pattern pieces out in readiness for toile development

ACTIVITY No.	ACTIVITY STEP DESCRIPTION
Activity 29	**Develop and deploy the fit pro forma** **Purpose:** To develop a document that analyses targeted portions of the garment prone to fitting errors for a mature 55+ demographic. To enable participants to critically analyse the garment only and not their body. The fit pro forma served to document the fit test. Steps undertaken: • Developed the fit pro forma using Adobe Illustrator and an anonymised scan image for the bodice visuals and Microsoft Word for the text • Identified garment fit issues from the questionnaire and transferred these into questions related to areas of the bodice • Referred to the 5 elements of fit within the unpublished Master's thesis. Documented these for the fit assessor. • Distributed the fit pro forma amongst the supervisory team to gain feedback prior to its deployment • Deployed the fit pro forma to the fit assessor during the fit test for bodice one and two • The fit assessor reads the questions to the participant and annotates the participants feedback • The fit assessor provides their own feedback based on the 5 elements of fit and any observations of the fitting process **NOTE:** Reoccurring garment fit issues were identified from the questionnaire **Objective [3]** (as seen in **Activity Step 14**). These garment fit issues were used to develop questions about the fit of certain parts of the bodice toile. The questions were designed to focus on the garment and not solicit discussion of an individual's body size or shape.
Activity 30	**Undertake the fit test** **Purpose:** To validate participant perceived waist position against scanner placed waist position (processed within the CDVELA process). To validate the landmark modifications within SLVM process within the context of a pattern/garment. Steps undertaken: • Confirmed participants wanted to participate • Completed an ethics form and asked for permission to photograph each bodice • Participants fitted on each bodice with help from the assessor if needed • The participant answered questions regarding the fit of different aspects of the bodice • Photographic evidence of each bodice's fit was gathered

ACTIVITY No.	ACTIVITY STEP DESCRIPTION
Activity 31	**Confirm improved garment fit** **Purpose: To determine which bodice the participant preferred in terms of its fit. To establish improved garment fit.** Steps undertaken: • Participants confirmed bodice preference in terms of its fit • Participants all chose bodice two which had been through both the SLVM and CDVELA processes and confirmed improved garment fit

Table 3-2 The activities within the research design (this table accompanies the research process map)

3.2.3 Evaluation of secondary data to frame and give purpose to the research (Activity 5)

The research commenced with a review of the academic knowledge base concerning anthropometric guidance (2.2), female gerontology/senescence (2.3.1; 2.3.2; 2.3.3) pattern construction (2.4, 2.4.1) industry practice and 3D-bodyscanning (2.10.2, 2.11) to provide a basis for the chosen methodologies and direction of the research (*Figure 3-1, Table 3-2*). These areas represent the broad spectrum of knowledge related to the ageing body and clothing development practice within the research question.

Key themes in the literature - ageing, automatic and traditional anthropometric measurement processes both and pattern construction methods - suggest this demographic are not being specifically accommodated by accustomed garment development practice that is applied in both educational (3.3) and industrial clothing settings (3.6.3; 3.7.2). Which has resulted in dissatisfaction with the fit of High street retailer's ready-to-wear clothing offer (3.6). The literature review established, by inductive reasoning, a basis for the direction of the research, as inductive reasoning looks for patterns in the data and projects it to new cases (Morton, 2004; Marshall, 1997). As inductive reasoning looks for patterns in the data and projects it to new cases, it was considered to be the more appropriate means of reasoning for this research paper. Induction was, therefore, able to establish the theoretical framework to observe the specific fields of enquiry, thereby enabling the detection of patterns and regularities (Marshall, 1997) within these fields with relation to the research question. A theoretical framework is defined as this in turn provided the means to propose a theory and develop a set of propositions, which were examined throughout Objectives [1] to [4] of the research.

In a more mature field of enquiry, deductive reasoning is often employed as the enquiry can draw upon established premises in order to produce logically sound deductions. However, in a newer field of enquiry such as this thesis, the theories proposed in the field thus far are less secure and, consequently, unable to provide established premises to use in deductive reasoning.

3.3 Key literature sources used to support the research design – the foundations of the research

This section cites key literature sources as they provided a grounding for the methods used by this research and demonstrated that both qualitative and quantitative data has been used in previous work, which meant this thesis should take a pragmatic view and a mixed method design when considering the methodology for this thesis (*Figure 3-1*, *Table 3-2*).

3.3.1 The rationale for an evaluation of past anthropometric surveys as a means of informing this methodology (Activity 5)

Determination of sample size, demographics and measurements were guided by previous international surveys (2.2). This qualitative guidance provided a benchmark for the design of this paper's anthropometric survey process for its target sample. The investigation of secondary data also indicated that 3D bodyscanner technology was prevalent for survey work, and that the non-contact methods of landmarking and measurement extraction used have derived from traditional anthropometric practice (2.8.1). Accordingly, to comprehend non-contact landmarking definitions and methods this thesis first had to understand the terminology (often medical in nature) used for traditional landmark definitions. It is also worth noting that it also had to become familiar with both computing and medical terminology to be able to work effectively with the participants, the landmarking regions and the 3D bodyscanner.

For the purposes of clarity this thesis defines the term 'computing terminology' as the vocabulary used by computer science researchers involved in the construction and development of 3D computing hardware and software systems as used in the discussion within section 2.7.3. Likewise, it also defines the term 'medical terminology' as the vocabulary used by researchers with a medical background involved in the exploration of age-related health observations and issues as used in the discussion within section 2.3.

3.3.2 The rationale for an evaluation of past anthropometric studies of mature women as a means of informing this methodology (Activity 5)

Secondary data from studies surrounding anthropometric practice for clothing construction was mainly quantitative as much of the work used body dimensions (provided by both traditional and non-contact anthropometric practice) to compare young and older female participants (2.5). The research detailed within section 2.5 – which discusses anthropometric surveys tailored for mature women - suggested and supported the development of an anthropometric survey for this paper. The literature with section 2.3.1 and 2.5 whose samples contained both a younger (18-25; 35-45) and mature (55+) female demographic, and also provided descriptive evidence to highlight that anthropometric practice and equipment often needed adaption for the older participant to effectively capture their body dimensions. Accordingly, this thesis understood that adaptations within the process of pre and post scanning would need to be a primary consideration when undertaking the anthropometric survey.

Qualitative data from the works discussed in section 2.5 also highlighted that there may issues in the recruitment of mature female participants as women in past research have not liked being seen in a state of semi undress. This information confirmed that 3D bodyscanning would be used by this paper as the survey instrument of choice because it facilitated privacy.

3.3.3 The rationale for analysis of pattern construction guidance alongside mature females fit preferences as a means of informing this methodology (Activity 5)

Key pattern measurements needed to be consolidated with the measurements provided by the 3D bodyscanner to enable patterns to be realised using the scanners quantitative outputs. Analysis of existing pattern construction and fit amendment methods confirmed these key measurements (2.4). Different diagrams of a mature female were used for the questionnaire and visual aid, whereby participants were invited to outline their fit preferences. Garment fit amendment literature (2.4.1) showed fit adjustment techniques targeted mainly mature women's body morphology using either photographs or diagrams of women who displayed a realistic mature physique. These images were supported by small paragraphs of annotation using commonplace terminology to describe the body. Questionnaires have previously been used for comparable studies such as those of Richards, 1981 or Goldsberry *et al* (1998) to gather participant's preferences of clothing fit, therefore this thesis sought to use a similar approach enabling this research to examine reported fit issues and determine if these aligned with known changes in body morphology due to the ageing process.

3.3.4 Female gerontology and body morphology changes as a means of informing this methodology (Activity 5)

Gerontological studies of women afforded understanding of body shape change through ageing (2.3), and the factors governing this change, particularly in relation to the deviation away from the accepted standard younger woman's morphology over time.

Medical literature (2.3), enable this thesis to clearly define the mature samples age as 55+ for this research as this is approximately 3 years after the average commencement of the menopause. Literature concerning ageing and body shape change (2.3) outlined the region of the body most prone to change. This information helped determine for this thesis that the torso should be the region of the body that is focused on for accurate landmarking, measurement extraction and pattern development. Therefore, the torso was the area of the body that this thesis would focus on for both landmarking and pattern construction.

3.3.5 3D bodyscanning technology's application within the clothing industry: skills acquisition to undertake the research (Activity 8)

It was necessary to develop skills and an understanding of the 3D bodyscanning software to undertake this research (*Figure 3-1, Table 3-2*: Activity 8). This is because portions of the methodology required the scanner to be utilised as a survey tool and the ensuing scans needed to be validated for accuracy, which meant understanding the different files types within the scanner and how landmarks can be modified needed to be undertaken. Literature focused on the exploration and application of 3D bodyscanning technology for the clothing industry contained few qualitative details of how the software intrinsically works (Gill *et al,* 2014b). Therefore, this research applied an experiential learning approach, via field research of the bodyscanner within the university to understand how to manipulate and apply the technology. Experiential learning is defined as means of learning or educating through first-hand experience of a task or situation (Kolb *et al*, 1999). The method uses real world experience and reflection to generate knowledge, and is closely aligned and has its intellectual origins within the philosophical worldview of pragmatism (Kolb *et al,* 1999) which is the philosophical worldview which guided this research, and which, will be discussed in the next section.

3.4 Research philosophy

3.4.1 The rationale for mixed methods

The literature as outline above (3.3) demonstrated that both qualitative and quantitative data methods and analysis have been used by different groups of researchers to explore the key themes of female gerontology, anthropometric practice, 3D bodyscanning and pattern construction. Using both qualitative and quantitative methods in one study is termed mixed methods research (Marshall, 1997; Burke-Johnson & Onwuegbuzie, 2004; Feilzer, 2010). Therefore, it was decided that a mixed methods research design would be used by this thesis for both data collection and analysis as its methodology is informed by the theoretical framework – from which a variety of methodologies have already been used - meaning this thesis's methodology is informed by and grounded in the literature.

3.4.2 The paradigm which guided this research - Pragmatism

Using mixed methods is considered a pragmatic approach within research philosophy (Burke-Johnson *et al,* 2007), as a mixed method strategy attempts to consider multiple viewpoints, perspectives and positions. Pragmatism, in a philosophical sense, is defined as a worldview that arises out of actions, situations and consequences, which emphasises the research question and uses all suitable approaches available to understand the problem (Creswell, 2009; Burke-Johnson *et al* 2007). Pragmatism, is known as the third research paradigm, the other two paradigms being positivism which posits that enquiry should be quantitative in nature and therefore objective, scientific and enable generalisation, and interpretivist/constructivism which posits that enquiry should be qualitative in nature and open to interpretation as they believe there are multiply realities and that cause and effect will never be truly differentiated (Burke-Johnson &

Onwuegbuzie, 2004. Mixed methods which is underpinned by a pragmatic worldview draws on the strengths of positivism and interpretivist/constructivism and rejects the weakness from both paradigms as it uses the most appropriate methods from both in terms of their fitness for purpose (Cohen *et al,* (2011). Therefore, this thesis's methodology did not strictly follow the dogma for each paradigm and instead took what Cohen *et al's* (2011: 23) – seasoned academic authors in research design - calls an 'eclectic, pluralist approach'. This means that the methodological design of this thesis allowed qualitative interpretation of data that was quantitative in nature such as textual discussion of descriptive statistics and vice versa, whereby qualitative data was quantised to form charts that showed the show the flow and frequency of emerging themes.

It was important that the outputs from this work were accessible for the clothing practitioner so that they could be easily adopted by the clothing industry and be meaningful to the clothing practitioner as well as impactful for women age 55+. Therefore the chosen paradigm – Pragmatism – which seeks to find solutions for the real world by producing 'socially useful [outcomes and] knowledge' (Feilzer, 2010: 6) provided this scope.

3.5 Proposition statement generation and the thesis argument

3.5.1 <u>The two primary concepts and proposition statements (Activity 6)</u>

Combining and synthesising data through the literature review indicated a number of emerging theories/concepts within the theoretical framework as seen in section 2.12. The two main concepts of this thesis are age and non-contact anthropometric measurement.

These two concepts were composed into a set of six proposition statements that would outline the research question (see *Table 3-3* below). This is because according to Zikmund *et al* (2013), propositions are statements concerned with associations among concepts and they can explain logical links between said concepts. Propositions are not dissimilar to a hypothesis in that both are units of theory development (Zikmund *et al*, 2013). However, where their point of difference is that a proposition can be general and difficult measure in that the concepts may not contain clear variable/units that can be tested. A hypothesis differs in that the statement/s has variables/units that are measurable. Its dogma is such that it strictly adheres to descriptive and inferential statistical testing which requires testable data from the start in order to be able to predict a particular outcome (Marshall, 1997).

Statement one: **3D bodyscanning technology is not 100% accurate in its landmarking capability, particularly when applied to non-standard body morphologies.**
Statement two: **Mature women's body size and shape undergoes age-related changes, which varies person to person, and can move the size and shape away from what is considered standard.**
Statement three: **Mature women have particular aesthetic and comfort related clothing requirements and can use these to inform clothing fit.**
Statement four: **Mature women have unique proprioceptive knowledge of their body.**
Statement five: **Mature women's proprioceptive knowledge can be used to improve the landmark positioning process within 3D bodyscanning technology.**
Statement Six: **Technician skilled in anthropometrics and 3D bodyscanning technology can interface with the system to evaluate and improve its landmarking accuracy.**

Table 3-3 The six proposition statements

Non-contact landmarking struggles to accurately landmark someone who displays a non-standard body size and shape as discussed in sections 2.7.4, 2.8 and 2.8.3, and mature women who have a non-standard body morphologies have unique proprioceptive knowledge of their body and particular clothing requirements which can be used to improve landmarking accuracy as discussed in section 2.3.5. A person who is skilled in anthropometrics, and has a good understanding of their 3D bodyscanner model can interface with it to evaluate its non-contact landmarking process and improve its landmark positioning. Statement one provided a rationale for the formation of a hypothesis which would test the scanner landmarking accuracy. The other statements would be tested using qualitative means, which will discussed later in this chapter.

3.6 Hypothesis generation

Hypothesis are explicitly stated propositions, consistent with theory, which are testable through experimental research according to Coolidge (2013). Marshal (2002:27) defines a hypothesis as a 'postulated connection between two or more variables'. Therefore, the hypothesis developed from the literature for this research was based on the causal relationships between the two variables illustrated below and is summarised within the literature review (2.7.4). It was determined that the hypothesis was of a directional nature, which is defined by Diamantopoulos & Schlegelmilch (2000) as a hypothesis indicating the direction of the expected differences in the variables due to previous a priori knowledge, that being the information extracted and discussed within the literature review.

The thesis had to examine the landmarking accuracy of the scanner when used for anthropometric measurement of an older female demographic (aged 55+) as landmarking are the start and end points for skin surface measurement and these body measurements are the precursor to clothing pattern development. Therefore, this thesis wanted to establish how it could improve the accuracy of landmarking thereby improving the fit of the pattern and the garment for the wearer.

The hypothesis statement needs to contain variables which can be tested by quantitative methods. The scanner provides body measurement values which can be measured and so it was determined that it is these units which could be tested, and which would appear within the hypothesis statement. Age is variable which this thesis posits affects the measurement accuracy and so age would form part of the hypothesis statement.

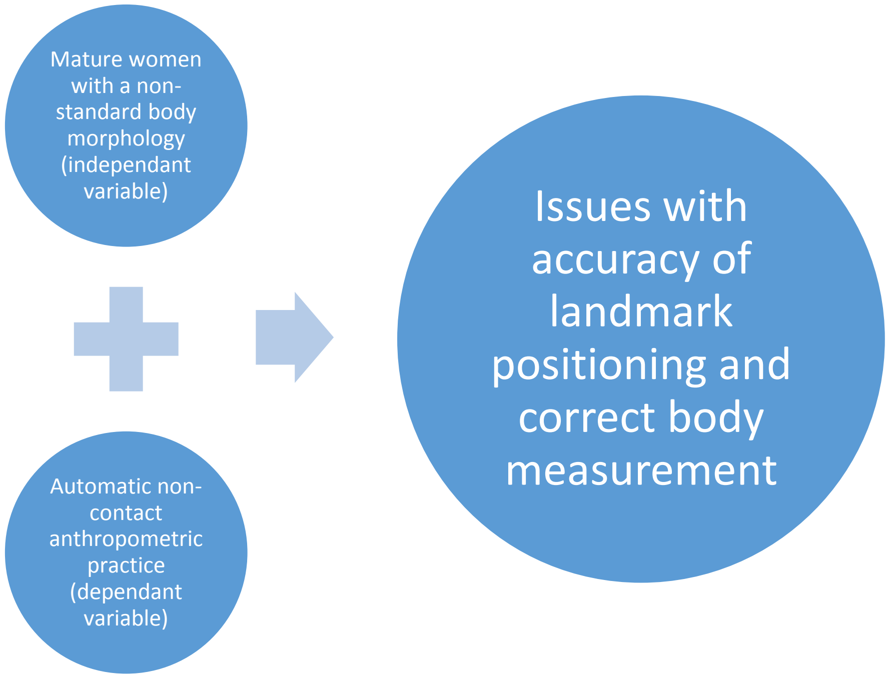


Figure 3-2 Theoretical Construct deduced from the knowledge base

3.6.1 The null hypothesis statement (Activity 7)

The independent variable of age-related body morphology change has no effect on the precision of dependant variable, automatic non-contact landmarking and the subsequent body measurements, and therefore these landmarks and ensuing body measurements do not require their accuracy validating.

3.6.2 The alternative hypothesis statement (Activity 7)

The independent variable of age-related body morphology change has an effect on the precision of the dependant variable, automatic non-contact landmarking and the subsequent body measurements and therefore, these landmarks and ensuing body measurements do require their accuracy validating.

Appropriate tests, involving both descriptive and inferential statistics, were selected to test the null hypothesis as part of Objective [3].

It should be noted at this point that although the research developed a hypothesis to test this was not the predominant feature of the research. Of course the research wanted to be able to generalise that the scanner cannot accurately landmark an older female demographic who explicitly display age-related body morphology changes as this would give purpose for the research. However, the primary reason was to enable participant engagement with the scanning process to improve garment fit. To facilitate this a process had to be developed which is the primary focus for this thesis.

3.7 Analysis of secondary data for the fulfilment of Objective [1] (qualitative methods)

Moving now to the work of Objective [1] and [2] (*Figure 3-1, Table 3-2*). Prior to the commencement of Objective [3] (testing the hypothesis and the SLVM and CDVELA processes) there was a period of skills acquisitions as it was deemed prudent to obtain a greater comprehension of how scanner technology operates and can be applied for Objective [1] and how its non-contact methods compared to manual measurement for Objective [2]. Both of these objectives used qualitative methods of content analysis and practical observations recorded as field notes.

Objective [1] is comprised of two elements. The first element required analysis of body measurement processes. The second element required analysis of the technologies used to implement these processes. These elements were further broken down into four areas for investigation, those being:

- Anthropometric practice
- Terminology used (both anatomical and computing)
- 3D-bodyscanning technology hardware and software
- Body landmarking methods

All four areas were developed concurrently as seen in *Figure 3-1* as it became apparent they were interrelated (*Figure 3-3)*. The data for the four areas was of a qualitative nature and therefore a process of data reduction was implemented for each area to ensure only pertinent data was used in the development of the conceptual model for Objective [2]. Data reduction required analysis of large volumes of text from secondary sources, selecting the most relevant comparative details and clustering condensed versions of these details into a tabular format. Therefore, the completion of Objective [1] provided a basis for the development of a conceptual model for Objective [2], which illustrated the different approaches to human body surface measurement, anatomical landmarking procedures, highlighted relationships between them and flagged their limitations.

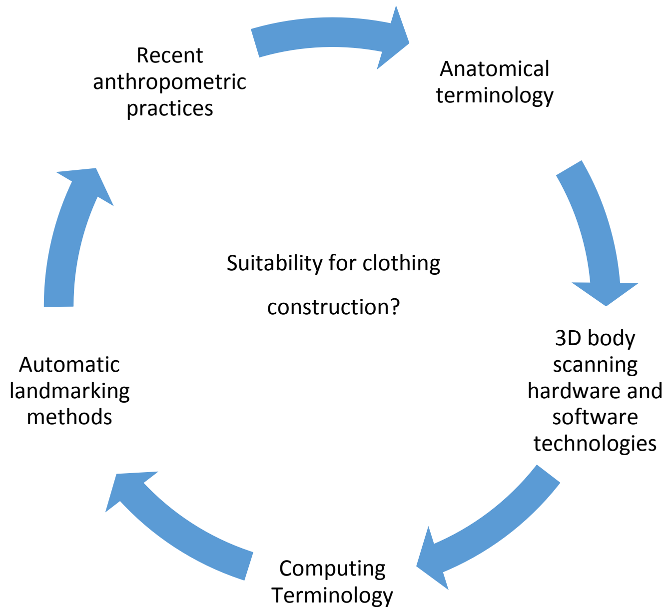


Figure 3-3 Concurrent analysis of secondary data

3.7.1 A survey review of Anthropometric surveys and their practice (Activity 11)

A survey of current adult anthropometric survey practice was undertaken to establish the methodologies and practices they had used to collect and analyse their body measurement data (*Figure 3-1, Table 3-2*). An Excel spreadsheet provided the repository for this survey of relevant adult sizing projects. Secondary data concerning project purpose, anthropometric methods used, sample size and type and number of body measurements taken, whether the survey had been published was gathered and structured into individual columns on the spreadsheet for ease of comparison (Appendix A). It was necessary to gather this information for two reasons. The first was to establish the purpose of each project as not all projects were specific to the clothing industry and therefore may include measurements unsuitable for garment construction. The second reason was to establish whether any previous projects had targeted females aged 55+ for data collection, as these particular projects may have tailored their practices specifically for this demographic thereby allowing this thesis to examine and adopt such practices if suitable.

3.7.2 3D-bodyscanning hardware and software (Activity 9)

Effective use of the 3D-bodyscanner as a data collection tool required an understanding of how both the hardware and software operate together, particularly as this thesis used two bodyscanner models with each using a different form of illumination. Details of proprietary 3D-bodyscanning systems were organised into a table using an Excel spreadsheet as shown in Appendix H. The table facilitated ready comparison between proprietary technologies and enabled a focused approach in gathering relevant details from the literature. These details were fundamental for two important phases of this thesis research, the first phase being able to correctly operate the scanner for the anthropometric survey that was necessary for data collection to test the hypothesis for Objective [3], and to instruct the participants during the scan so that clear scans were captured and any reasons for miss-scans were established. The second phase was to ascertain how the scanner assesses the skin surface when placing the landmarks.

This thesis differed from previous studies (2.7.4) in that it sought to provide a comparative analysis of various 3D-bodyscanning systems using both proprietary promotional and academic sources focused on the same proprietary scanner system.

3.7.3 Surveying landmarking methods developed by academics to determine ease of use by a clothing practitioner (Activity 10)

Academic studies concerning anatomical practice were reviewed (*Figure 3-1, Table 3-2*). Only studies relevant to clothing generation were isolated as sources of information. Many of these studies had practices that were novel and blended both traditional and non-contact landmarking practice. Data from these studies both populated and informed the development of the landmarking methods table for this thesis, which can be found within Appendix M.

Using a tabular format in Excel for the table of landmarking methods meant that column headings provided focus for relevant information. This in turn would allow the separation of information into data entities and therefore would form the beginnings of the conceptual model, which presented a new assemblage of different approaches to the measurement of the human form and was the output of Objective [2].

The studies were analysed, first for ease of use by a clothing practitioner, as new training/skills acquisition might be necessary to implement the landmarking method. Secondly, for the precision the landmarking method would provide for females aged 55+. Thirdly, for compatibility of the method with the TC^2 3D-bodyscanning system, as this system was identified as a convenience sample for data collection, which collected the data to test the null hypothesis thereby providing new knowledge necessary for the achievement of Objective [3].

3.8 Conceptual model development for Objective [2] (qualitative methods)

Several research models were evaluated for appropriateness for this thesis. Relational models were first considered as they are based on a tabular structure and demonstrate relational links from column to column (Sheldon, 2003). However, this model was rejected as its primary use is for constructing and understanding databases, which is not appropriate for this part of the study. The conceptual model selected as the most appropriate way to present the different approaches to human body measurement, as they vary by method and a simplified structure was required to express the many differences. This type of model was chosen to represent the landmarking process as its structure allows for the key factors, entities or ideas (in this case the landmarking process for both manual and automatic anthropometric practice) to be positioned in a graphical way. This graphical representation allows relational links to be visualised thereby presenting an organised and compressed assemblage of the information that would allow for the drawing of conclusions and verification (Miles & Hubermann, 1993).

The conceptual model was this research's method of presented the different approaches to human body measurement. It facilitated comparison of different anthropometric techniques to establish relationships between traditional and automatic anatomical landmarking and was developed to formalise each process as nothing of this nature could be found in the literature. Formalisation was necessary as there was nothing within the literature which indicated how automatic landmarking has evolved (Objective [2]), because it allowed the process of automatic landmarking to be analysed against the problems encountered in previous research (2.5) when establishing landmarks on a non-standard body morphology.

The conceptual model was developed using data collected from secondary and primary sources. These were academic literature focused on both manual and non-contact anthropometric practice (2.2.1; 2.7.2; 2.7.3), 3D bodyscanning marketing literature (Appendix H) and experiential learning of the scanner via training opportunities offered by a senior lecturer in the Department of Apparel. Additional experiential learning of the newer scanner model occurred during the anthropometric survey of mature women aged 55+ whereby the NX16 model was replaced by the KX16 model. This learning was documented through handwritten field notes detailing the process (*Figure 3-1, Table 3-2*: Activities 8, 9, 10 and 11).

3.8.1 <u>Generating the model (Activity 12)</u>

Qualitative data from the landmarking methods and the 3D-bodyscanning hardware and software Excel sheets informed and populated the conceptual model. This data was extracted using analysis of the content of each piece of literature. In addition, experiential knowledge of using the TC^2 scanner to collect data for Objective [3] also provided observational information (field notes) of how non-contact landmarking operates. This qualitative information and practical knowledge helped map the steps of each of the three anthropometric approaches.

The Excel tables generated to fulfil Objectives [1] and [2] enabled relevant information to be extracted from the anthropometric and computer science literature and then organised. Manual, semi-automatic and automatic methods of landmarking were broken down (via analysis of the content of the literature) into how the processes worked/flowed and from this relational associations were made.

This information was then graphically represented as a conceptual model in Adobe Illustrator, which allowed for flexibility that facilitated amendment. The model was this research's view of the three different modes of human skin surface body measurement, which was governed, by what was present in the literature and practical experience of the technology.

3.8.2 Evaluating the effectiveness of the model (Objective [3]) by comparing the 55+ sample to women aged 18-25 and 35-45 (Activities 15 and 16)

The model – for Objective [2] was developed to graphically illustrate how the environment differs between manual, semi-automatic and automatic means of body measurement extraction and this information provided a backdrop for the next stage of the research - Objective [3] which would gather anthropometric data from women aged 55+ to test the null hypothesis (3.6).

3.9 The 55+ anthropometric survey Objective [3] (both qualitative and quantitative methods)

At this point the methodology collect and analysed qualitative data for Objective [1] and [2] for the as that data came in the form of academic studies, scanner branding and marketing material, field notes and observations. Objective [3] required quantitative data and methods, as it was this Objective, which began to test the null hypothesis. This therefore is where the methodology begins to use the mixed method approach (3.4.1).

Objective [3] took the longest time in terms of data collection (4 years) and analysis (2 years) and so this section of the methodology chapter is lengthy. Sections 3.9.1-3.10.4 will discuss the data collection phase of Objective [3] and following this sections 3.11.1-3.12.13 will discuss data analysis. Each section title will be prefixed with either 'Data collection' or 'Data Analysis' to make it easier to follow.

3.9.1 Data collection - scanners used for 55+ anthropometric survey (Activity 15)

Two TC^2 scanners were used to collect body measurement data for females over 55 years. To establish a baseline for the accuracy of the 3D-bodyscanning method scans were analysed from demographic groups that were more likely to contain standard body morphologies (younger women). Therefore, the research thesis reviewed existing dimensional scan data of women from the 18-25 and 35-45-year old demographic groups within the university's scanner database and compared the accuracy of the landmark positions against the landmark positions on the 55+ demographic. The rationale for this was that the younger demographics were less likely to have undergone the type of changes to body morphology associated with ageing and the menopause, which may manifest great accuracy in landmark positioning and require less intervention to ensure correct measurement. These two samples in terms of recruitment and analysis are discussed in greater detailer further on in this chapter (3.10).

3.9.2 Data collection - rationale for usage of the TC² scanners and survey locations (Activity 15)

The 55+ anthropometric survey was held in two different geographical locations: the NX16 in Manchester and KX16 in Nottingham. The TC² brand had been used previously for the SizeUK and SizeUS anthropometric surveys, and was designed specifically for clothing purposes (Simmons & Istook, 2003).

As opposed to manual and semi-automated methods of landmarking, the TC² standard software employs an automatic landmarking method. Practical investigation by this thesis confirmed the automatic landmarking method did not change even though two different TC² scanner models were used. Therefore, this particular phase of the anthropometric survey was fully (automatic) non-contact, using the original software programming, and without any intervention from the operator of the scanner.

3.9.3 Data collection - scanner configuration and participant posture adoption (Activity 15)

The hardware configuration for the TC² NX16 in Manchester and the TC² KX16 in Nottingham were comparable in terms of the internal layout, the camera configuration and the technical interface, therefore the hardware required no modification for the purposes of this research as all participants in the survey would be exposed to the same configuration, this meant the scanner hardware and software acted as the control against the independent variable of age-related body shape/size change and the dependant variable of automatic non-contact landmarking.

As the internal layout of both systems were the same, this meant that participants were obliged to take the same stance within the devices. The BS EN ISO 20685:2010, standardises scanning posture as standing within the scanner in the anatomical position with the head facing forward, feet slightly apart and the hands slightly away from the sides. TC² provides information regarding foot positioning on the floor. All participants were instructed to adopt the standard scan posture advised by TC², feet placed at the foot positions (approx. 30-40cm apart) and arms away from the body holding the handholds.

3.9.4 Data collection - measurements offered to the participant – MEP used (Activity 15)

A Measure Extraction Parameter (here after MEP) was developed by clothing academics within the university for use in clothing related research and was therefore selected as the MEP most appropriate to be shared with the participant along with a visual of the scan. This MEP file was termed the '02_4cm_tolerance-(reduced)'. This MEP was akin to the SizeUK MEP, in that it used a similar coding system and set of landmark definitions, but rather than give the participant 144 measurements, some of which bore no relation to the design or production of clothing, the MEP gave only 92 relevant body measurements.

As part of the aim of this thesis is to improve clothing fit in the female 55+ demographic, therefore using a MEP which was similar to the SizeUK MEP was considered the best approach. This was because this MEP had been developed specifically for the clothing industry for clothing development (Sizemic, 2010), and would have some bearing on the current sizing of clothing products within the UK.

3.9.5 Data collection - recruitment strategies for the 55+ sample (Activity 15)

Previous research has indicated a reluctance in this demographic to be measured (2.5). Therefore In order to supply the sample population for the 3D-bodyscanning survey (3.1), recruitment of female participants aged 55+ followed four different approaches so the survey could be communicated to as many women aged 55+ as possible.

- Approach 1: Posters were designed to advertise the research (Appendix I) and these were placed in public areas such as libraries, health clubs, beauty salons, and doctors' surgeries within the Greater Manchester environs.
- Approach 2: An email campaign targeting MMU university staff.
- Approach 3: The earliest participants of the survey were encouraged to recommend the survey to female 55+ friends and family, if they chose to do so.

- Approach 4: Three womenswear retailers who were interested in the potential of 3D-bodyscanning technology to improve the fit of their products were entered into partnership with. These retailers advertised via the internet and local radio to recruit individuals for a scanning survey held over three days in Nottingham.

The participant samples from approaches 1-3 used were conveniently accessible to the research and frequently selected using a non-probability sampling technique, meaning they could be termed a convenience sample (Maisel & Hodges Persell, 1996; Saratakos, 2005). Although the sample was a convenience sample, the participants had to fall within specific criteria to be able to participate within the research. The criteria being that subjects had to be aged 55 years or over, be female and be physically able to stand within the scanning booth for the time it took to capture their body surface data. Participants of different heights, body shapes and sizes were invited to participate.

Participant samples from recruitment approach 4 were determined to be a random sample due to the nature of how the survey was advertised to the general population. A random selection strategy of sampling means each individual has an equal probability of being selected from the population frame (Creswell, 2009), so although the criteria for selection was in place, anyone who responded to the adverts were accepted for scanning.

This mixed sampling approach can add confidence to the findings (Miles & Huberman, 1994), as it can offer the opportunity to identify whether a finding is affected by the method of sampling chosen.

3.9.6 Data collection - size of the sample being scanned (Activity 15)

The sample size of the research was reliant upon the selected demographic, the willingness of subject participation, time/cost/manpower considerations, and comparable surveys in academic literature.

The sample size for the 55+ segment of the research was 80 subjects. Following a clearly developed criteria that had been tested and refined using the TC^2 body scanners (Gill *et al* 2014b), this thesis focused on the development of a process for evaluating the accuracy of the landmarking algorithm through individual observation and evaluation of each subjects scan data that is both visual and numerical. The research also required participant input into the modification their landmarks, something that is novel and had not been undertaken previously by any comparable study thereby contributing to new knowledge in the field.

Previous anthropometric surveys with some comparisons to this research thesis with small sample sizes are as follows:

Study	Sample size	Age	Gender
Kouchi & Mochimaru (2011)	20	21-59	females
Sims *et al* (2012)	15 (able bodied)	60+	Males & females
Han & Nam (2011)	60	20-69	Males & females

Table 3-4 Comparable studies sample sizes

Not all of these studies have explicitly identified the ratio of ages and genders within their sample whereas this particular research project is explicit in terms of both gender and age range. Therefore, this thesis has, to date, provided the largest sample of females aged 55+ for this particular type of anthropometric survey.

Notwithstanding, Beazley (1997) and Pheasant (1990) have suggested a sample of 500 subjects is recommended provided they are a representative sample, although Beazley's (1997) survey used a sample of 100 women. It should be noted, however, that both of Beazley's (1997) and Pheasant's (1990) studies focused on the collection of large amounts of body dimensional data to inform the development of size charts based on averages generated from the sample rather than on the close examination and analysis of individual scans from both a qualitative and quantitative viewpoint as this thesis has done.

This thesis scan evaluation process was something that was outside of the scope of Beazley's (1997), whose approach observed processed the data for error outliers and then used statistical calculation to develop size charts and grade intervals. As the size of sample for this research was greater than that of the comparable studies of Kouchi & Mochimaru (2011); Sims *et al* (2012) and Han & Nam (2011), 80 subjects was determined to be a sufficient sample size for the purposes of this research and would be representative.

Close examination and analysis of individual scans quantitative (the dimensional measurements and landmark positions) and qualitative data (the scan image) as well as reflective engagement with the scan subject (to find out what they think of their measurements and they key body dimension position), was required as part of the process of scan evaluation. Following the processing of the scan data descriptive statistics (mean and standard deviation) to demonstrate the distribution of the quantitative data and inferential statistics (T-test) to test the null hypothesis and provide generalisations of the results were undertaken to test the null hypothesis.

3.9.7 Data collection - scanning process and protocols (Activities 15)

The scanning process (Appendix O) had to be approved by the MMU ethics committee before the survey could take place. Prior to the scan day, participants were given a written and visual account of the scan process and were informed they could withdraw at any time (Appendix O). This was verbally reiterated when participants arrived to be scanned. Participants' personal details were recorded on a password protected database using Filemaker Pro, which allocated each person with a code for anonymity. Participants were required to sign a consent form to be eligible for scanning. All forms were stored in a safe and the database was on a separate pc to the TC^2 scanner software ensuring another level of security.

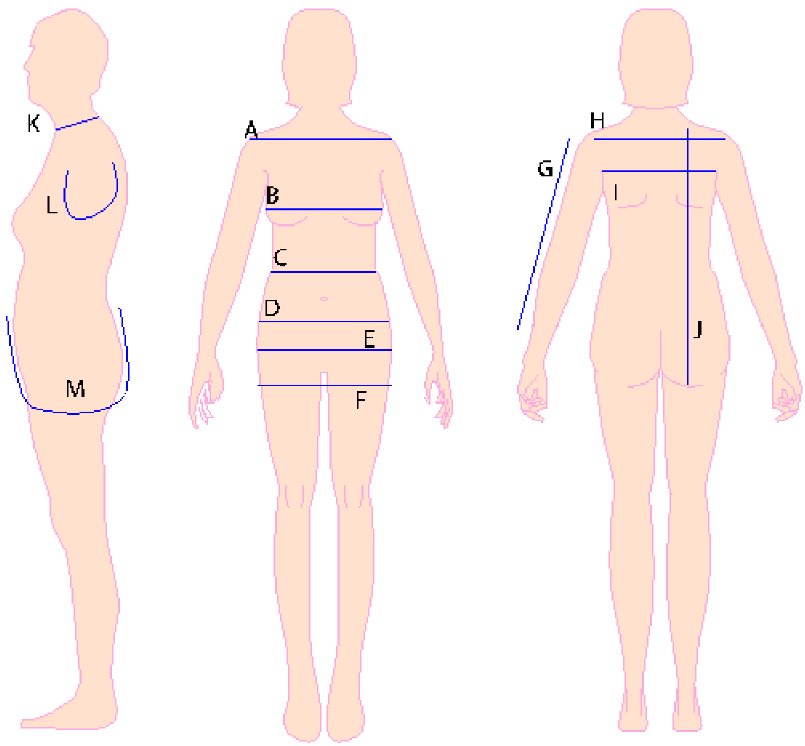
During the survey observations were noted via handwritten field notes both pre- and post-scanning so qualitative data concerning participants perceptions and reactions to recruitment and the scanning process, including the responses to the visuals were accurately documented for later analysis. King's (2014) summary of the survey process using 3D bodyscanning technology with a particular emphasis on TC^2's brand of scanner states that a positive participant experience will determine successful registration and ultimately achieve target sample numbers. This research confirmed King's (2014) conclusion as to recruit an older demographic and provide further opportunities to engage with participant's post-scan survey, a positive experience was crucial to create an environment of trust.

All participants wore their own underwear in line with the Size UK's survey. Participants were shown how to stand in the scanner and were scanned three times to ensure a clear scan. Both King (2014) and the BS EN ISO 20685:2010 recommends this practice to ensure at least one accurate scan. Once dressed participants were asked if they wanted to see their scan on screen and if they wanted a scan printout.

3.9.8 Data collection – questionnaires and the visual aid (Activities 13 and 14)

The questionnaire phase of this mixed methodology allowed participants voice their concerns over garment fit, provide retailer preference and to engage with the evaluation of scan data by specifying waist landmark position preference for clothing and where they felt their natural waist was. The data provided by the questionnaire was both qualitative in that it contained open ended questions which required written responses from the participants and quantitative in that some questions were closed and yes, no or categories for participants to choose. The data could be termed nominal in that some questions required participants to choose a category.

Both the visual aid and questions on clothing retailer preference and garment fit were piloted using two Manchester Metropolitan University academics from the Department of Apparel, both of whom fitted all the recruitment criteria and had experience of the clothing product development process. Feedback from the pilot identified some of the questions needed clarification such by providing images to show where poor fit was experienced on the body (*Figure 3-4*).



Garments do not fit me properly in the following area/s					
A front shoulders	B bust	C waist	D hip	E bottom	F thighs
G arms	H back shoulders	I across the back	J torso length	K neck	L underarm
M crotch					

Figure 3-4 Image developed to enable participants to indicate where poor fit occurs on their body.

The pilot also indicated that the visual aid needed to be simple but not idealised (*Figure 3-5*). It was also determined that the visuals would depict the following definitions in a visually explicit form:

A. Using the spinal curves and placed above the small of the back with a 2.5” tolerance – (Devarajan and Istook, 2004)

B. Using the spinal curves and placed above the small of the back with a 4cm tolerance – provided within the TC^2 software. This definition was used in the Size UK study

C. Using the spinal curves and placed at the small of the back – (Kirchdoerfer *et al*, 2002)

D. At the point of the top of the iliac crest – Wang *et al* (2003)

Table 3-5 Four definitions of the waist culled from literature

The above definitions in Table 3-5 were selected because they have been used in previous research centred on anthropometric practice and they had enough scope to place the waist at visually different intervals.

The sample of subjects aged 55+ were given a semi-structured questionnaire to gather data on the proprioception (Appendix J: questions 6 and 7) of their perceived landmarked areas, garment fit issues, garment preferences and shopping habits which were used further on in the research for Objectives [4] and [5]. Proprioception is the conscious and unconscious sensory awareness of the position and placement of the body (Johnson & Soucacos, 2010) and, as such, played a role in the subjective evaluation in the identification of landmarks on their own bodies.

The questionnaires enabled participant involvement within the landmark placement evaluation process, something that no other study had done in this way before. The questions were informed by findings from literature concerning body shape change. The questions were also informed by the measurements required for pattern development and a review of reported fit issues in fit alteration literature. Fit issues and garment preference data was further used for Objective [3], which involved testing landmark/measurement placement using the development and amendment of patterns that covered the top portions of the torso to the waist. Fit analysis of the resulting constructed garments was undertaken using the fit criteria developed in a study by Wren and Gill (2010).

Two visual aids were developed to allow for the collection of subjective data provided by the participants of the questionnaire (*Table 3-2*: Activity 14). Other comparable studies such as those of Haffenden, 2009, Song and Ashdown, 2013, have used visual aids in questionnaires but the visual aids in this research project were designed to allow for interactive participant reflection and subjective data gathering, therefore these visual aids provide newness in three registers:

1 A new tool has been provided that allows for feedback between the operator and the participant.
2 The simplicity of the visuals allows for the ready implementation of the tool in industry as it is largely self-evident and, hence, would require minimal training.
3 The tool allows for a synthesis of manual and automatic landmarking methods, which, in turn, facilitates the cleaning and modification of the data to provide a more accurate scan for clothing development.

Within the questionnaire, participants were asked to observe where they believed their waist position to be by identifying which of the four images below represented the participant's waist (*Figure 3-5)*.

The images in (*Figure 3-4*; *Figure 3-5* and *Figure 3-6*).were developed from an anonymised scan of the 55+ demographic. This particular scan image was chosen because it was an actual scanned image of a woman from the 55+ demographic. As this image was not a standardised aspirational image used by the clothing industry, the body shape contained therein was deemed to look natural and so would be familiar to the subject. The position of each waistline on the each image was determined through the observation of waist landmark placement using the MEP definitions 'small of the back' and 'narrowest indentation'.

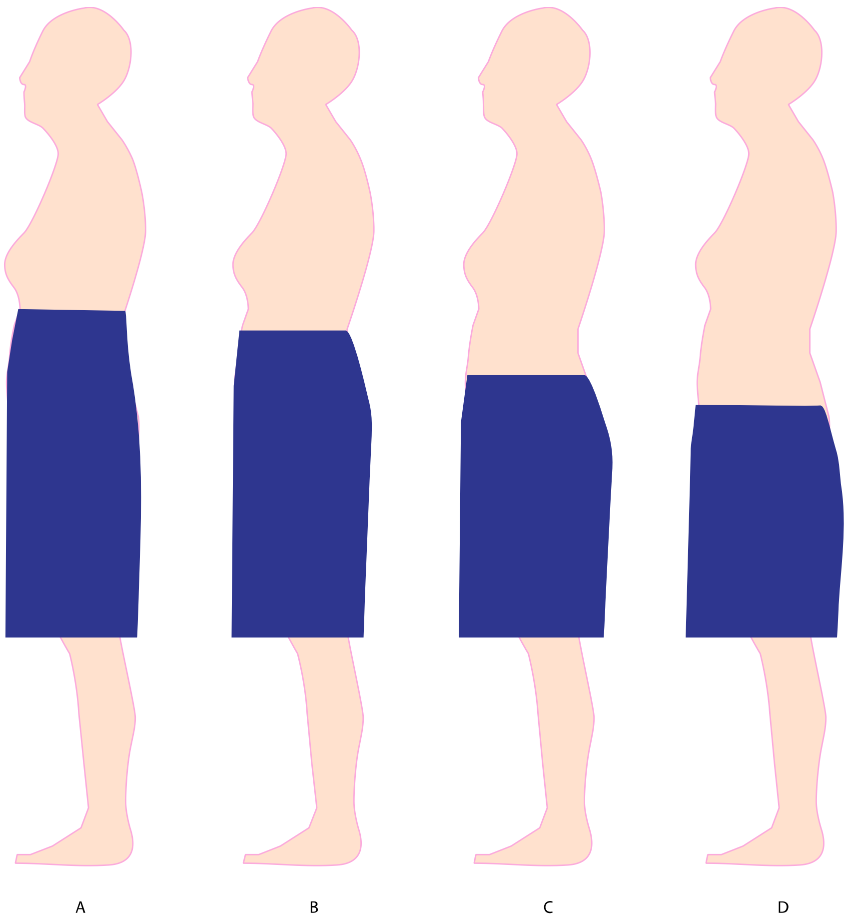


Figure 3-5 Visual of where participants selected preferred waistband position

Participants in the questionnaire were required to observe and note the waistband position of the garments they wore on the day of the scan and to identify this waist landmark position through the use of another set of images (*Figure 3-6*).

As with the images in *Figure 3-5* above, these visuals were again developed not using a standardised aspirational image, as used by the clothing industry, therefore the body shape contained therein was deemed to look natural and, hence, familiar to the subject. Participants' responses were then compared to the waist position on their actual individual scans and the differences between the automatic waist placement performed by the software and the waist placements identified through the use of the visual aids were recorded for comparison.

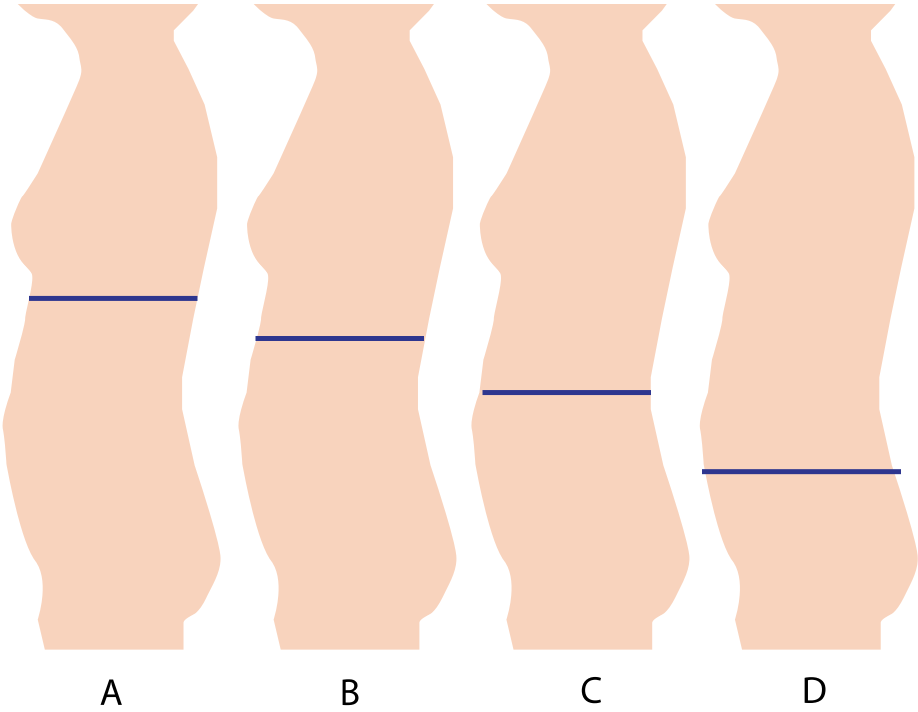


Figure 3-6 Participants actual waistband position

3.9.9 Data collection - final 55+ sample size (Activities 13, 14 and 15)

As stated earlier, 80 participants, aged 55+ were recruited and scanned. This sample number further reduced as only 52 of the 80 scanned also participated in the use of the visual aid within the questionnaire that constituted a part of the methodology of this research. The BS EN ISO 20685:2010 standard recommends a sample size of 40 participants '[as] this will ensure 95 % confidence in the validation test results for large circumferences such as chest, waist, and hip, which are particularly difficult to measure for both traditional and 3-D measurement systems'. As this study used a sample of 52, an increase on the recommended 40, this study justifies a high level of confidence in the validation of its own results.

3.10 Comparing the 55+ scans to younger females scan data – visual observation

3.10.1 Data collection - rationale for including younger samples (Activity 16)

To examine the null hypothesis (3.6.1) for Objective [3], the 55+ scan data needed comparing to that of a younger sample (*Figure 3-1, Table 3-2*: Activity 16). Previous research has suggested that, generally, younger women have a more clearly defined waist and that waist definition is less visually apparent as a women ages (2.3.3). The research wanted to explore if this is the case and whether it has an impact on how the scanner identifies and landmarks the waist. Previous studies have also sought to compare women of varying ages to understand how morphological change impacts on a garment's fit (3.2.2) and as this research used comparative garment patterns to identify how changes in body shape impact on pattern geometry. However, Haffenden (2009) also suggests that a sampling frame with a greater age range can be useful to establish similarities and differences in body shape and size and how these impacts on measurement protocols.

3.10.2 Data collection - method of obtaining the scans (Activity 16)

The scans of women from the 18-25 and 35-45 demographic were selected using a purposive sampling technique from a larger database of scans captured using both body scanner models at MMU. These scans were all captured following the standard scanning process (Appendix O) used to capture all scans with the TC2² scanners at MMU, including the older demographic scans for this research.

3.10.3 Data collection - identifying and separating the younger sample scan codes (Activity 16)

The TC² software stores the scans under unique codes (generated by Filemaker Pro) but does not have a search specific field's facility to isolate participant scan of a particular age or gender. As mentioned previously, (3.9.7) University scanner database contained all the scan codes and height values for each participant and most importantly, for the purposes of this research, it had a search by specific field facility, which saved time.

The database was on a separate pc to the TC² scanner and contained all the scan codes, participant ages, heights/weights, ethnicity, contact details and gender information. Scan data can provide numerous measurements and any one of these could have been used as a criterion for participant selection within the younger demographics. However, it was determined that the search criteria of age and gender was sufficient for the purposes of this research. The database's search facility meant scan codes using these criteria could be quickly isolated and copied into an Excel spreadsheet.

3.10.4 Data collection - sampling strategies for the 18-25 and 35-45 year old samples (Activity 16)

The final total of the 55+ sample was 52 (3.9.9) and so it was decided that 104 scans in total (52 of each demographic) would be to be used to compare to those of the 55+ scans, following the method of quota sampling, where there is an equal number of participants within each age bracket (Maisel & Hodges-Persell, 1996). This was not possible as the database at that time only contained 38 participants from the 35-45 age bracket whereas the 18-25 age bracket totalled 1584 in population size. Therefore, this research was obliged to use two sampling methods - convenience and probability/random - as there was a strict time limit enforced by the university to undertake the work so this research could not be expanded to begin recruitment of a new demographic.

In order to maintain a sample of 104 to compare with the 52 samples of the 55+ participants, 66 scans from the 18-25 age bracket were used to supplement the 38 scans from the 35-46 age bracket. The 66 scans 18-25 year old were selected using Excel's random number generator function. The entire 1584 set of scans were exported into Excel and each scan code was allocated a number. These allocated Excel numbers were then resorted from the lowest number to the highest. The first 66 scans generated were culled from this list.

3.11 Scan validation and modification process

3.11.1 Data analysis - evaluating the scan data visuals (qualitative) (Activity 17 and 18)

The study's entire sample underwent two scan data evaluation processes (*Figure 3-1, Table 3-2*: Activities 17 and 18). Each scan required a multi-faceted approach including qualitative (a visual evaluation of the scans) and quantitative (an analysis of the numerical measurement data). This evaluation and analysis entailed the development of novel processes not previously discussed in any historical or current literature.

The first process (*Table 3-2:* Activity 17) was one of qualitative evaluation whereby all scans were checked for viability and modified if required. This visual evaluation allowed for every landmark, from the chin point to the ankles, to be inspected for placement accuracy and allowed for the correction of landmarking errors where possible. Where there were significant gaps of data in the scans, these scans were discarded (Gill *et al*, 2014b). This was prudent practice to ensure erroneous data was isolated so as not to skew any results.

The second process (*Table 3-2*: Activity 18), developed exclusively for this research, combined qualitative evaluation coupled with quantitative analysis to facilitate focusing the landmarking analysis to a specific area of the body (the torso) and explored the reasons for any errors. This second process enabled comparison between the younger and older demographics in terms of how many landmarking errors are present along this area of the body, why have they occurred and whether age-related morphology changes were a causal element. This second process also allowed the input of the questionnaire data provided by the participants of the 55+ sample to determine perceived waist position.

Though both first and second processes are novel, it is this second process that allows participant engagement in the scanning event. This is a distinctive first in this type of research. Both processes are discussed in detail below.

3.11.2 Data analysis - first process – Scan Landmark Validation and Modification (here after known as SLVM) (Activity 17)

Previous research (King, 2014) discussed that scan data goes through a system of evaluation to check viability prior to analysis; therefore, there is a clear precedent for cleaning data before analysis. However, detailed guidance on how to undertake this cleaning process is lacking (Gill *et al,* 2014b). For the purposes of this research, a set of scan validation and landmark modification protocols (SLVM) were developed (*Figure 3-7*) to validate the quality of scan image and accuracy of landmark placements within individual scans.

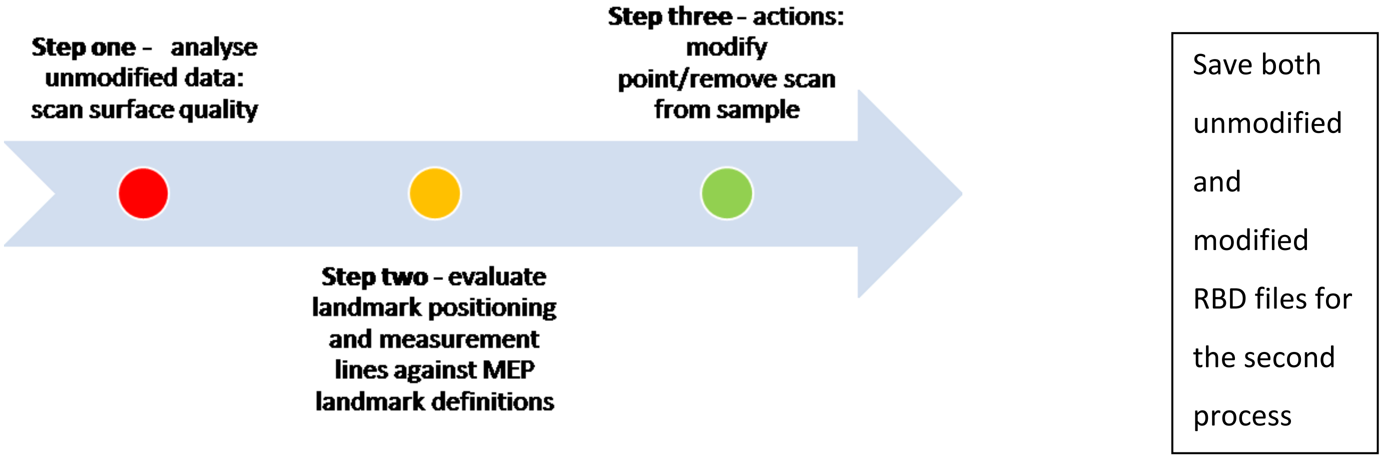


Figure 3-7 First process - SLVM

3.11.3 Data analysis - first process involving the MEP file used (Activity 17)

Following the identification of the lack of guidance regarding the cleaning of scans in "Practical Considerations of Applying Body Scanning as a Teaching and Research Tool" (Gill *et al* 2014b, Appendix AI of which this research directly contributed) this same team of academics from the MMU Department of Apparel developed the SLVM protocols (*Table 3-2:* Activity 17). The team - professional anthropometric practitioners in 3D-bodyscanning - used their empirical knowledge of anthropometrics to inform a heuristic approach. The SLVM protocols necessitated that scans be opened in TC^2 and evaluated by a practitioner to identify the clarity of the scan image and accuracy of the landmarking. An expanded version of the '02_4cm_tolerance' MEP was used to extract the body measurements during this SLVM process. Whereas the standard '02_4cm_tolerance' MEP had 92 measurements, this expanded version of the '02_4cm_tolerance' contained 209 measurements, 117 additional measurements to those supplied by the standard '02_4cm_tolerance' MEP. Whereas the standard '02_4cm_tolerance' MEP was tailored to the utility of the participants of the scan survey, this expanded MEP provided additional measurements, many of which were from both the left and right sides of the body, and was tailored to the skillset of professional anthropometric practitioners. This new expanded MEP was labelled '03_4cm_tolerance' MEP.

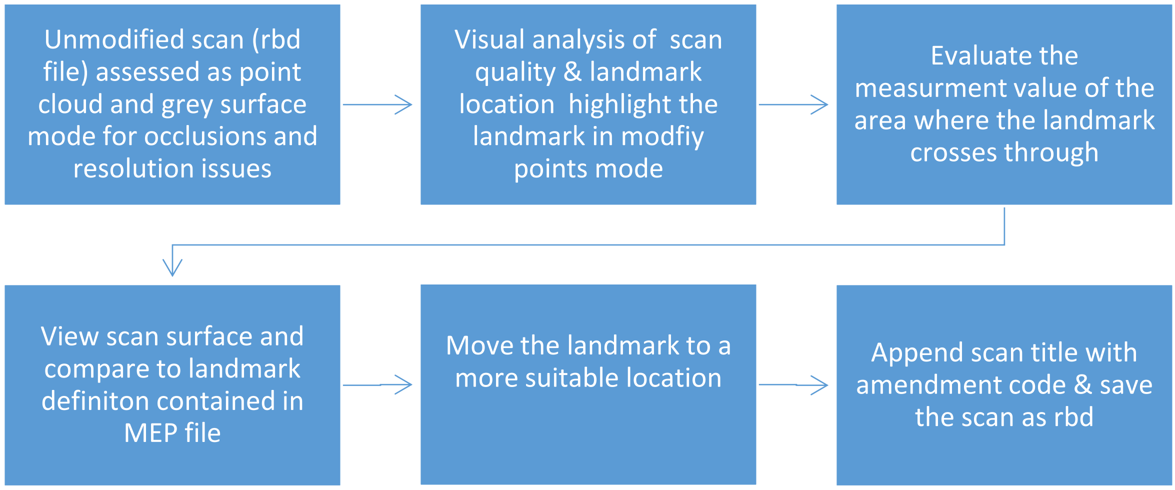


Figure 3-8 Scan and landmark modification and validation process map (Activity 17)

The team viewed each scan and any that were visually clear but had landmarking errors were corrected by moving the landmarks to the most appropriate position based on observation of the skin surface and analysis of the landmark definition within the MEP file (Appendix Q). Members of the team identified whether landmark modification was required and, if required, the modify point tool (*Figure 3-9*) found within the TC^2 software interface was used.

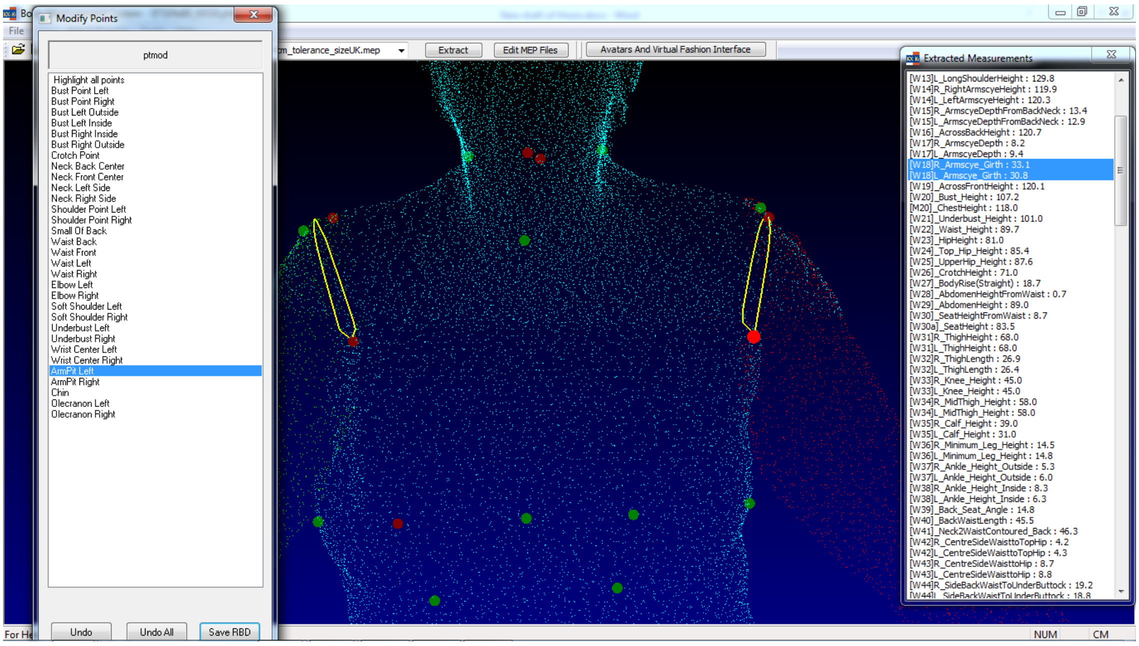


Figure 3-9 Modify point facility

Once completed both the original and modified scans were saved to different folders within TC2 which was secured in line with MMU's ethical framework, ensuring the modified scans were appended with letters depicting which landmarks had been modified (Appendix P). This allowed for other members of the team to access both versions of the file along with simple notes detailing what landmarks had been moved on the TC2 system. Allowing the viewing of both unmodified and modified scans enabled the team to appraise each other's work, learn from each other, and reach a consensus on landmark modification. However, it should be noted that the pre- and post-modification scans were not compared to each other.

The SLVM process was purely to check the usability of each scan and amend the landmark points if needed to make them viable for research. If scans were unable to be used, due to occlusions or excessive noise in the scan data, the SLVM process had the potential to reduce the samples size for this study. Any scans with unmodifiable errors were separated from the rest of the sample and will be discussed in the next chapter.

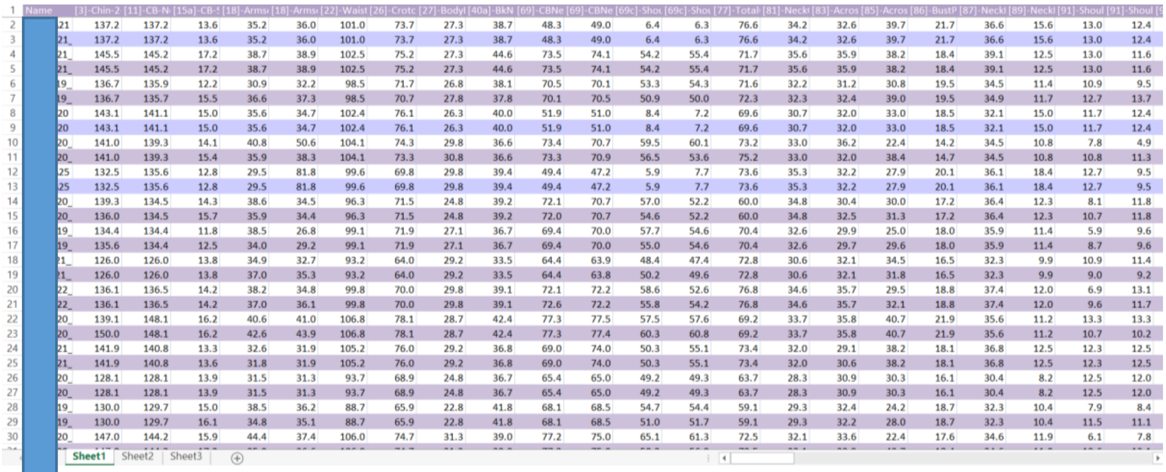
3.12 Comparing the 55+ quantitative scan data to the 18-25 and 35-45 sample

3.12.1 <u>Data analysis - testing the null hypothesis (Activity 19)</u>

This thesis theorises that morphological change is more apparent with ageing. Moreover, the thesis hypothesises that landmarking a mature female body using the standard measurement definitions within the scanner software may prove to be inaccurate. Therefore, this research tested the hypothesis (3.6.1) using female participants whose age range spanned from 18-55+ years and body morphology was varied to see if indeed age-related morphological change was the predominant element for errors in landmarking *Table 3-2*: Activities 16, 17, 18 and 19).

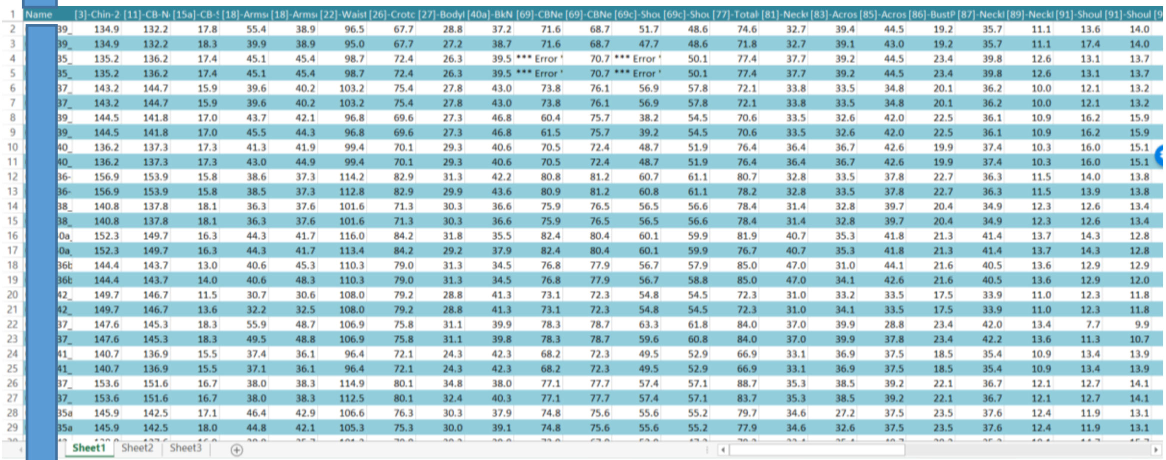
3.12.2 Data analysis - batch processing each of the demographic samples to prepare the data for inferential statistical analysis (Activity 19)

Each demographic was still kept separate at this point so the mean and standard deviation could be calculated for each age group's body measurement change. The same 03_4cm_tolerance MEP was used as before. Both unmodified and modified scan data was exported into a spreadsheet using the batch process facility within TC^2 (*Figure 3-11*). To make it easier to identify which were unmodified and modified scan data values the Excel cells were coloured white for original and a colour for modified depending on the demographic (*Figure 3-10*).



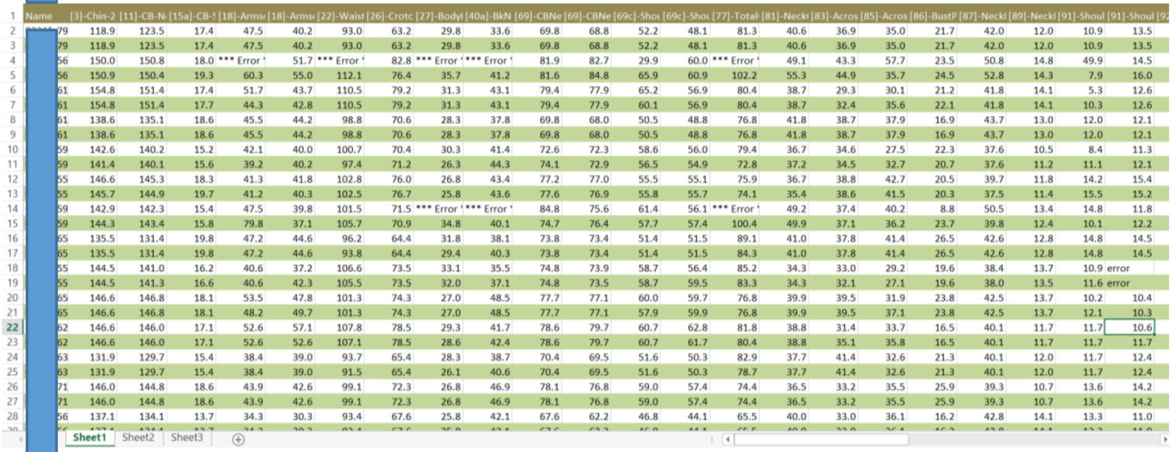
	Name	[3]-Chin-2	[11]-CB-N	[15a]-CB-	[18]-Arms	[18]-Arms	[22]-Waist	[26]-Crotc	[27]-Bodyl	[40a]-BkN	[69]-CBNe	[69]-CBNe	[69c]-Shou	[69c]-Shou	[77]-Total	[81]-Neck	[83]-Acros	[85]-Acros	[86]-BustP	[87]-Neckl	[89]-Neckl	[91]-Shoul	[91]-Shoul
2	[redacted]	137.2	137.2	13.6	35.2	36.0	101.0	73.7	27.3	38.7	48.3	49.0	6.4	6.3	76.6	34.2	32.6	39.7	21.7	36.6	15.6	13.0	12.4
3	[redacted]	137.2	137.2	13.6	35.2	36.0	101.0	73.7	27.3	38.7	48.3	49.0	6.4	6.3	76.6	34.2	32.6	39.7	21.7	36.6	15.6	13.0	12.4
4	[redacted]	145.5	145.2	17.2	38.7	38.9	102.5	75.2	27.3	44.6	73.5	74.1	54.2	55.4	71.7	35.6	35.9	38.2	18.4	39.1	12.5	13.0	11.6
5	[redacted]	145.5	145.2	17.2	38.7	38.9	102.5	75.2	27.3	44.6	73.5	74.1	54.2	55.4	71.7	35.6	35.9	38.2	18.4	39.1	12.5	13.0	11.6
6	[redacted]	136.7	135.9	12.2	30.9	32.2	98.5	71.7	26.8	38.1	70.5	70.1	53.3	54.3	71.6	32.2	31.2	30.8	19.5	34.5	11.4	10.9	9.5
7	[redacted]	136.7	135.7	15.5	36.6	37.3	98.5	70.7	27.8	37.8	70.1	70.5	50.9	50.0	72.3	32.3	32.4	39.0	19.5	34.9	11.7	12.7	13.7
8	[redacted]	143.1	141.1	15.0	35.6	34.7	102.4	76.1	26.3	40.0	51.9	51.0	8.4	7.2	69.6	30.7	32.0	33.0	18.5	32.1	15.0	11.7	12.4
9	[redacted]	143.1	141.1	15.0	35.6	34.7	102.4	76.1	26.3	40.0	51.9	51.0	8.4	7.2	69.6	30.7	32.0	33.0	18.5	32.1	15.0	11.7	12.4
10	[redacted]	141.0	139.3	14.1	40.8	50.6	104.1	74.3	29.8	36.6	73.4	70.7	59.5	60.1	73.2	33.0	36.2	22.4	14.2	34.5	10.8	7.8	4.9
11	[redacted]	141.0	139.3	15.4	35.9	38.3	104.1	73.3	30.8	36.6	73.3	70.9	56.5	53.6	75.2	33.0	32.0	38.4	14.7	34.5	10.8	10.8	11.3
12	[redacted]	132.5	135.6	12.8	29.5	81.8	99.6	69.8	29.8	39.4	49.4	47.2	5.9	7.7	73.6	35.3	32.2	27.9	20.1	36.1	18.4	12.7	9.5
13	[redacted]	132.5	135.6	12.8	29.5	81.8	99.6	69.8	29.8	39.4	49.4	47.2	5.9	7.7	73.6	35.3	32.2	27.9	20.1	36.1	18.4	12.7	9.5
14	[redacted]	139.3	134.5	14.3	38.6	34.5	96.3	71.5	24.8	39.2	72.1	70.7	57.0	52.2	60.0	34.8	30.4	30.0	17.2	36.4	12.3	8.1	11.8
15	[redacted]	136.0	134.5	15.7	35.9	34.4	96.3	71.5	24.8	39.2	72.0	70.7	54.6	52.2	60.0	34.8	32.5	31.3	17.2	36.4	12.3	10.7	11.8
16	[redacted]	134.4	134.4	11.8	38.5	26.8	99.1	71.9	27.1	36.7	69.4	70.0	57.7	54.6	70.4	32.6	29.9	25.0	18.0	35.9	11.4	5.9	9.6
17	[redacted]	135.6	134.4	12.5	34.0	29.2	99.1	71.9	27.1	36.7	69.4	70.0	55.0	54.6	70.4	32.6	29.7	29.6	18.0	35.9	11.4	8.7	9.6
18	[redacted]	126.0	126.0	13.8	34.9	32.7	93.2	64.0	29.2	33.5	64.4	63.9	48.4	47.4	72.8	30.6	32.1	34.5	16.5	32.3	9.9	10.9	11.4
19	[redacted]	126.0	126.0	13.8	37.0	35.3	93.2	64.0	29.2	33.5	64.4	63.8	50.2	49.6	72.8	30.6	32.1	31.8	16.5	32.3	9.9	9.0	9.2
20	[redacted]	136.1	136.5	14.2	38.2	34.8	99.8	70.0	29.8	39.1	72.1	72.2	58.6	52.6	76.8	34.6	35.7	29.5	18.8	37.4	12.0	6.9	13.1
21	[redacted]	136.1	136.5	14.2	37.0	36.1	99.8	70.0	29.8	39.1	72.6	72.2	55.8	54.2	76.8	34.6	35.7	32.1	18.8	37.4	12.0	9.6	11.7
22	[redacted]	139.1	148.1	16.2	40.6	41.0	106.8	78.1	28.7	42.4	77.3	77.5	57.5	57.6	69.2	33.7	35.8	40.7	21.9	35.6	11.2	13.3	13.3
23	[redacted]	150.0	148.1	16.2	42.6	43.9	106.8	78.1	28.7	42.4	77.3	77.4	60.3	60.8	69.2	33.7	35.8	40.7	21.9	35.6	11.2	10.7	10.2
24	[redacted]	141.9	140.8	13.3	32.6	31.9	105.2	76.0	29.2	36.8	69.0	74.0	50.3	55.1	73.4	32.0	29.1	38.2	18.1	36.8	12.5	12.3	12.5
25	[redacted]	141.9	140.8	13.6	31.8	31.9	105.2	76.0	29.2	36.8	69.0	74.0	50.3	55.1	73.4	32.0	30.6	38.2	18.1	36.8	12.5	12.3	12.5
26	[redacted]	128.1	128.1	13.9	31.5	31.3	93.7	68.9	24.8	36.7	65.4	65.0	49.2	49.3	63.7	28.3	30.9	30.3	16.1	30.4	8.2	12.5	12.0
27	[redacted]	128.1	128.1	13.9	31.5	31.3	93.7	68.9	24.8	36.7	65.4	65.0	49.2	49.3	63.7	28.3	30.9	30.3	16.1	30.4	8.2	12.5	12.0
28	[redacted]	130.0	129.7	15.0	38.5	36.2	88.7	65.9	22.8	41.8	68.1	68.5	54.7	54.4	59.1	29.3	32.4	24.2	18.7	32.3	10.4	7.9	8.4
29	[redacted]	130.0	129.7	16.1	34.8	35.1	88.7	65.9	22.8	41.8	68.1	68.5	51.0	51.7	59.1	29.3	32.2	28.0	18.7	32.3	10.4	11.5	11.1
30	[redacted]	147.0	144.2	15.9	44.4	37.4	106.0	74.7	31.3	39.0	77.2	75.0	65.1	61.3	72.5	32.1	33.6	22.4	17.6	34.6	11.9	6.1	7.8

Sheet1 Sheet2 Sheet3



	Name	[3]-Chin-2	[11]-CB-N	[15a]-CB-	[18]-Arms	[18]-Arms	[22]-Waist	[26]-Crotc	[27]-Bodyl	[40a]-BkN	[69]-CBNe	[69]-CBNe	[69c]-Shou	[69c]-Shou	[77]-Total	[81]-Neck	[83]-Acros	[85]-Acros	[86]-BustP	[87]-Neckl	[89]-Neckl	[91]-Shoul	[91]-Shoul
2	[redacted]	134.9	132.2	17.8	55.4	38.9	96.5	67.7	28.8	37.2	71.6	68.7	51.7	48.6	74.6	32.7	39.4	44.5	19.2	35.7	11.1	13.6	14.0
3	[redacted]	134.9	132.2	18.3	39.9	38.9	95.0	67.7	27.2	38.7	71.6	68.7	47.7	48.6	71.8	32.7	39.1	43.0	19.2	35.7	11.1	17.4	14.0
4	[redacted]	135.2	136.2	17.4	45.1	45.4	98.7	72.4	26.3	39.5	*** Error	70.7	*** Error	50.1	77.4	37.7	39.2	44.5	23.4	39.8	12.6	13.1	13.7
5	[redacted]	135.2	136.2	17.4	45.1	45.4	98.7	72.4	26.3	39.5	*** Error	70.7	*** Error	50.1	77.4	37.7	39.2	44.5	23.4	39.8	12.6	13.1	13.7
6	[redacted]	143.2	144.7	15.9	39.6	40.2	103.2	75.4	27.8	43.0	73.8	76.1	56.9	57.8	72.1	33.8	33.5	34.8	20.1	36.2	10.0	12.1	13.2
7	[redacted]	143.2	144.7	15.9	39.6	40.2	103.2	75.4	27.8	43.0	73.8	76.1	56.9	57.8	72.1	33.8	33.5	34.8	20.1	36.2	10.0	12.1	13.2
8	[redacted]	144.5	141.8	17.0	43.7	42.1	96.8	69.6	27.3	46.8	60.4	75.7	38.2	54.5	70.6	33.5	32.6	42.0	22.5	36.1	10.9	16.2	15.9
9	[redacted]	144.5	141.8	17.0	45.5	44.3	96.8	69.6	27.3	46.8	61.5	75.7	39.2	54.5	70.6	33.5	32.6	42.0	22.5	36.1	10.9	16.2	15.9
10	[redacted]	136.2	137.3	17.3	41.3	41.9	99.4	70.1	29.3	40.6	70.5	72.4	48.7	51.9	76.4	36.4	36.7	42.6	19.9	37.4	10.3	16.0	15.1
11	[redacted]	136.2	137.3	17.3	43.0	44.9	99.4	70.1	29.3	40.6	70.5	72.4	48.7	51.9	76.4	36.4	36.7	42.6	19.9	37.4	10.3	16.0	15.1
12	[redacted]	156.9	153.9	15.8	38.6	37.3	114.2	82.9	31.3	42.2	80.8	81.2	60.7	61.1	80.7	32.8	33.5	37.8	22.7	36.3	11.5	14.0	13.8
13	[redacted]	156.9	153.9	15.8	38.5	37.3	112.8	82.9	29.9	43.6	80.9	81.2	60.8	61.1	78.2	32.8	33.5	37.8	22.7	36.3	11.5	13.9	13.8
14	[redacted]	140.8	137.8	18.1	36.3	37.6	101.6	71.3	30.3	36.6	75.9	76.5	56.5	56.6	78.4	31.4	32.8	39.7	20.4	34.9	12.3	12.6	13.4
15	[redacted]	140.8	137.8	18.1	36.3	37.6	101.6	71.3	30.3	36.6	75.9	76.5	56.5	56.6	78.4	31.4	32.8	39.7	20.4	34.9	12.3	12.6	13.4
16	[redacted]	152.3	149.7	16.3	44.3	41.7	116.0	84.2	31.8	35.5	82.4	80.4	60.1	59.9	81.9	40.7	35.3	41.8	21.3	41.4	13.7	14.3	12.8
17	[redacted]	152.3	149.7	16.3	44.3	41.7	113.4	84.2	29.2	37.9	82.4	80.4	60.1	59.9	76.7	40.7	35.3	41.8	21.3	41.4	13.7	14.3	12.8
18	[redacted]	144.4	143.7	13.0	40.6	45.3	110.3	79.0	31.3	34.5	76.8	77.9	56.7	57.9	85.0	47.0	31.0	44.1	21.6	40.5	13.6	12.9	12.9
19	[redacted]	144.4	143.7	14.0	40.6	48.3	110.3	79.0	31.3	34.5	76.8	77.9	56.7	58.8	85.0	47.0	34.1	42.6	21.6	40.5	13.6	12.9	12.0
20	[redacted]	149.7	146.7	11.5	30.7	30.6	108.0	79.2	28.8	41.3	73.1	72.3	54.8	54.5	72.3	31.0	33.2	33.5	17.5	33.9	11.0	12.3	11.8
21	[redacted]	149.7	146.7	13.6	32.2	32.5	108.0	79.2	28.8	41.3	73.1	72.3	54.8	54.5	72.3	31.0	34.1	33.5	17.5	33.9	11.0	12.3	11.8
22	[redacted]	147.6	145.3	18.3	55.9	48.7	106.9	75.8	31.1	39.9	78.3	78.7	63.3	61.8	84.0	37.0	39.9	28.8	23.4	42.0	13.4	7.7	9.9
23	[redacted]	147.6	145.3	18.3	49.5	48.8	106.9	75.8	31.1	39.8	78.3	78.7	59.6	60.8	84.0	37.0	39.9	37.8	23.4	42.2	13.6	11.3	10.7
24	[redacted]	140.7	136.9	15.5	37.4	36.1	96.4	72.1	24.3	42.3	68.2	72.3	49.5	52.9	66.9	33.1	36.9	37.5	18.5	35.4	10.9	13.4	13.9
25	[redacted]	140.7	136.9	15.5	37.1	36.1	96.4	72.1	24.3	42.3	68.2	72.3	49.5	52.9	66.9	33.1	36.9	37.5	18.5	35.4	10.9	13.4	13.9
26	[redacted]	153.6	151.6	16.7	38.0	38.3	114.9	80.1	34.8	38.0	77.1	77.7	57.4	57.1	88.7	35.3	38.5	39.2	22.1	36.7	12.1	12.7	14.1
27	[redacted]	153.6	151.6	16.7	38.0	38.3	112.5	80.1	32.4	40.3	77.1	77.7	57.4	57.1	83.7	35.3	38.5	39.2	22.1	36.7	12.1	12.7	14.1
28	[redacted]	145.9	142.5	17.1	46.4	42.9	106.6	76.3	30.3	37.9	74.8	75.6	55.6	55.2	79.7	34.6	27.2	37.5	23.5	37.6	12.4	11.9	13.1
29	[redacted]	145.9	142.5	18.0	44.8	42.1	105.3	75.3	30.0	39.1	74.8	75.6	55.6	55.2	77.9	34.6	32.6	37.5	23.5	37.6	12.4	11.9	13.1

Sheet1 Sheet2 Sheet3



	Name	[3]-Chin-2	[11]-CB-N	[15a]-CB-	[18]-Arms	[18]-Arms	[22]-Waist	[26]-Crotc	[27]-Bodyl	[40a]-BkN	[69]-CBNe	[69]-CBNe	[69c]-Shou	[69c]-Shou	[77]-Total	[81]-Neck	[83]-Acros	[85]-Acros	[86]-BustP	[87]-Neckl	[89]-Neckl	[91]-Shoul	[91]-Shoul
2	[redacted]	118.9	123.5	17.4	47.5	40.2	93.0	63.2	29.8	33.6	69.8	68.8	52.2	48.1	81.3	40.6	36.9	35.0	21.7	42.0	12.0	10.9	13.5
3	[redacted]	118.9	123.5	17.4	47.5	40.2	93.0	63.2	29.8	33.6	69.8	68.8	52.2	48.1	81.3	40.6	36.9	35.0	21.7	42.0	12.0	10.9	13.5
4	[redacted]	150.0	150.8	18.0	*** Error	51.7	*** Error	82.8	*** Error	*** Error	81.9	82.7	29.9	60.0	*** Error	49.1	43.3	57.7	23.5	50.8	14.8	49.9	14.5
5	[redacted]	150.9	150.4	19.3	60.3	55.0	112.1	76.4	35.7	41.2	81.6	84.8	65.9	60.9	102.2	55.3	44.9	35.7	24.5	52.8	14.3	7.9	16.0
6	[redacted]	154.8	151.4	17.4	51.7	43.7	110.5	79.2	31.3	43.1	79.4	77.9	65.2	56.9	80.4	38.7	29.3	30.1	21.2	41.8	14.1	5.3	12.6
7	[redacted]	154.8	151.4	17.7	44.3	42.8	110.5	79.2	31.3	43.1	79.4	77.9	60.1	56.9	80.4	38.7	32.4	35.6	22.1	41.8	14.1	10.3	12.6
8	[redacted]	138.6	135.1	18.6	45.5	44.2	98.8	70.6	28.3	37.8	69.8	68.0	50.5	48.8	76.8	41.8	38.7	37.9	16.9	43.7	13.0	12.0	12.1
9	[redacted]	138.6	135.1	18.6	45.5	44.2	98.8	70.6	28.3	37.8	69.8	68.0	50.5	48.8	76.8	41.8	38.7	37.9	16.9	43.7	13.0	12.0	12.1
10	[redacted]	142.6	140.2	15.2	42.1	40.0	100.7	70.4	30.3	41.4	72.6	72.3	58.6	56.0	79.4	36.7	34.6	27.5	22.3	37.6	10.5	8.4	11.3
11	[redacted]	141.4	140.1	15.6	39.2	40.2	97.4	71.2	26.3	44.3	74.1	72.9	56.5	54.9	72.8	37.2	34.5	32.7	20.7	37.6	11.2	11.1	12.1
12	[redacted]	146.6	145.3	18.3	41.3	41.8	102.8	76.0	26.8	43.4	77.2	77.0	55.5	55.1	75.9	36.7	38.8	42.7	20.5	39.7	11.8	14.2	15.4
13	[redacted]	145.7	144.9	19.7	41.2	40.3	102.5	76.7	25.8	43.6	77.6	76.9	55.8	55.7	74.1	35.4	38.6	41.5	20.3	37.5	11.4	15.5	15.2
14	[redacted]	142.9	142.3	15.4	47.5	39.8	101.5	71.5	*** Error	*** Error	84.8	75.6	61.4	56.1	*** Error	49.2	37.4	40.2	8.8	50.5	13.4	14.8	11.8
15	[redacted]	144.3	143.4	15.8	79.8	37.1	105.7	70.9	34.8	40.1	74.7	76.4	57.7	57.4	100.4	49.9	37.1	36.2	23.7	39.8	12.4	10.1	12.2
16	[redacted]	135.5	131.4	19.8	47.2	44.6	96.2	64.4	31.8	38.1	73.8	73.4	51.4	51.5	89.1	41.0	37.8	41.4	26.5	42.6	12.8	14.8	14.5
17	[redacted]	135.5	131.4	19.8	47.2	44.6	93.8	64.4	29.4	40.3	73.8	73.4	51.4	51.5	84.3	41.0	37.8	41.4	26.5	42.6	12.8	14.8	14.5
18	[redacted]	144.5	141.0	16.2	40.6	37.2	106.6	73.5	33.1	35.5	74.8	73.9	58.7	56.4	85.2	34.3	33.0	29.2	19.6	38.4	13.7	10.9	error
19	[redacted]	144.5	141.3	16.6	40.6	42.3	105.5	73.5	32.0	37.1	74.8	73.5	58.7	59.5	83.3	34.3	32.1	27.1	19.6	38.0	13.5	11.6	error
20	[redacted]	146.6	146.8	18.1	53.5	47.8	101.3	74.3	27.0	48.5	77.7	77.1	60.0	59.7	76.8	39.9	39.5	31.9	23.8	42.5	13.7	10.2	10.4
21	[redacted]	146.6	146.8	18.1	48.2	49.7	101.3	74.3	27.0	48.5	77.7	77.1	57.9	59.9	76.8	39.9	39.5	37.1	23.8	42.5	13.7	12.1	10.3
22	[redacted]	146.6	146.0	17.1	52.6	57.1	107.8	78.5	29.3	41.7	78.6	79.7	60.7	62.8	81.8	38.8	31.4	33.7	16.5	40.1	11.7	11.7	10.6
23	[redacted]	146.6	146.0	17.1	52.6	52.6	107.1	78.5	28.6	42.4	78.6	79.7	60.7	61.7	80.4	38.8	35.1	35.8	16.5	40.1	11.7	11.7	11.7
24	[redacted]	131.9	129.7	15.4	38.4	39.0	93.7	65.4	28.3	38.7	70.4	69.5	51.6	50.3	82.9	37.7	41.4	32.6	21.3	40.1	12.0	11.7	12.4
25	[redacted]	131.9	129.7	15.4	38.4	39.0	91.5	65.4	26.1	40.6	70.4	69.5	51.6	50.3	78.7	37.7	41.4	32.6	21.3	40.1	12.0	11.7	12.4
26	[redacted]	146.0	144.8	18.6	43.9	42.6	99.1	72.3	26.8	46.9	78.1	76.8	59.0	57.4	74.4	36.5	33.2	35.5	25.9	39.3	10.7	13.6	14.2
27	[redacted]	146.0	144.8	18.6	43.9	42.6	99.1	72.3	26.8	46.9	78.1	76.8	59.0	57.4	74.4	36.5	33.2	35.5	25.9	39.3	10.7	13.6	14.2
28	[redacted]	137.1	134.1	13.7	34.3	30.3	93.4	67.6	25.8	42.1	67.6	62.2	46.8	44.1	65.5	40.0	33.0	36.1	16.2	42.8	14.1	13.3	11.0

Sheet1 Sheet2 Sheet3

Figure 3-10 Examples of colour coded unmodified and modified batch processed scan data – white are the original data and coloured cells are modified

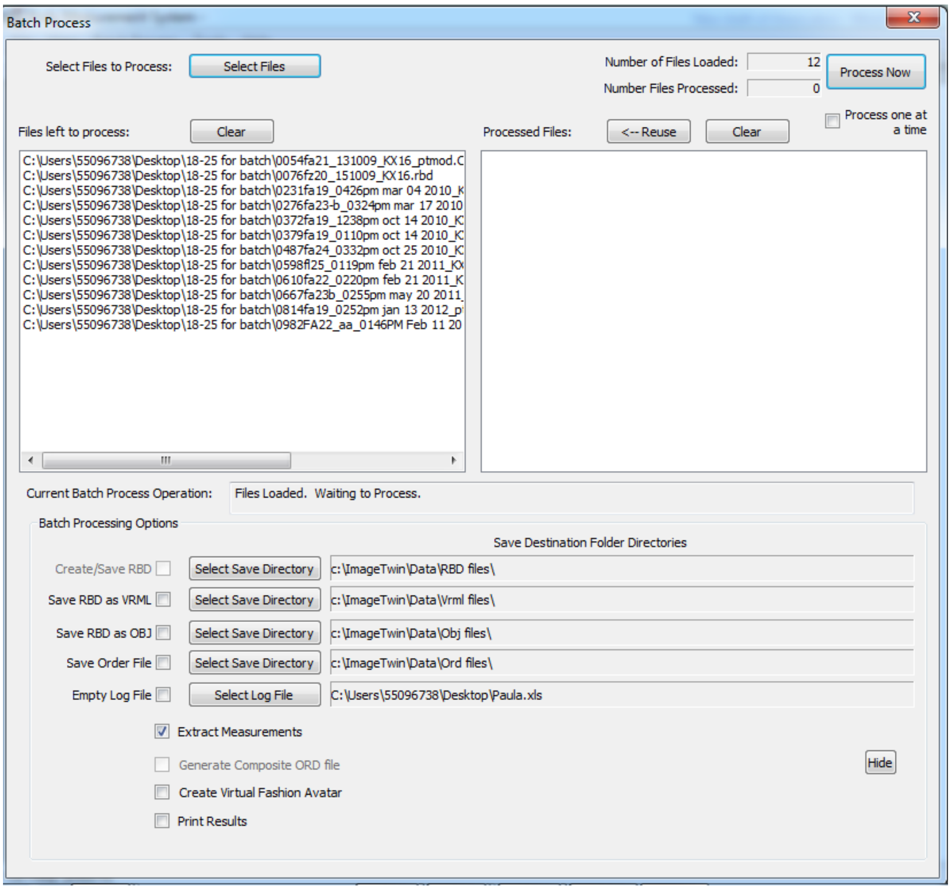


Figure 3-11 Batch process facility

3.12.3 Data analysis - evaluating and calculating measurement 'value difference' between original and modified landmarks – preparing the data for statistical analysis (Activity 19)

The scanner combines landmarks to give height and girth measurements. An example of this would be the waist girth measurement, whereby the scanner software places landmark markers on the back, front and sides of the torso around where its algorithm defines the waist to be. A line can then run through each marker to connect them and give a complete body measurement, which the scanner terms waist girth. The MEP used does not output the landmark coordinates and examination of the scanner database interface revealed that there was no direct facility for this. Therefore the data had to be examined to see how landmark modification could be illustrated using the measurements provided. Measurement which provide height measurements from the floor were selected as a difference in height can clearly show if the landmark has moved up or down. Girth measurement were different as once their landmarks were moved they showed differences in girth measurement and not height. This change in measurement be it girth or height would demonstrate a change in the landmark which would then indicate the scanner had not placed the landmark correctly in the first instance. Therefore to prepare the data for analysis this thesis collated both unmodified and modified body measurements for both girth and height measurements (Table 3-6), subtracting the modified body measurement from the original to show the numerical difference between the two. This thesis termed it the ‘value difference’ as shown in *Table 3-6*. This was done for commonly misplaced landmarks in each of the age clusters and was a lengthy but necessary process to ensure the landmarks were accurately placed.

Once this calculation had been undertaken for each age cluster the remaining values were compared between the different demographic groups to see if one particular age cluster had large value differences. If a body measurement was significantly different once a landmark had been modified it could suggest the definition (which is based on a standard body morphology) within the scanner for that landmark was not appropriate for that person’s body size and shape. The comparisons were documented in Excel so that charts could be generated to show the findings.

1	e [40a]-BkNeck-2-WaistLength-(e) original	e [40a]-BkNeck-2-WaistLength- (e) cleaned	Value difference	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	Value difference	h [??]-SideNeck2Waist-overbust-(h) original	h [??]-SideNeck2Waist-overbust-(h)cleaned	Value difference	g [??]-SideNeck2Bust-R-(g) original	g [??]-SideNeck2Bust-R-(g) cleaned	Value difference	I W83 Xback before cleaned	I W83 Xback after cleaning	Value difference	j W85 X f before cleanin
2	37.2	38.7	-1.5	18.7	19.3	-0.6	40.7	42.2	-1.5	29.4	29.4	0.0	39.4	39.1	0.3	44
3	39.5	39.5	0.0	18.9	18.9	0.0	45.8	45.8	0.0	30.8	30.8	0.0	39.2	39.2	0.0	44
4	43.0	43	0.0	17.5	17.5	0.0	47.7	47.7	0.0	28.3	28.3	0.0	33.5	33.5	0.0	34
5	46.8	46.8	0.0	18.6	18.6	0.0	47.9	47.9	0.0	29.9	30.0	0.0	32.6	32.6	0.0	42
6	40.6	40.6	0.0	19.5	19.5	0.0	47.2	47.2	0.0	32.0	32.0	0.0	36.7	36.7	0.0	42
7	42.2	43.6	-1.4	18.1	18.1	0.0	45.8	47.0	-1.2	32.7	32.7	0.0	33.5	33.5	0.0	37
8	36.6	36.6	0.0	18.6	18.6	0.0	40.6	40.6	0.0	25.6	25.6	0.0	32.8	32.8	0.0	39
9	35.5	37.9	-2.4	17.2	17.2	0.0	44.6	45.7	-1.2	32.9	32.9	0.0	35.3	35.3	0.0	41
10	34.5	34.5	0.0	13.4	14.7	-1.3	42.2	42.2	0.0	29.0	29.0	0.0	31.0	34.1	-3.1	44
11	41.3	41.3	0.0	12.8	14.9	-2.1	43.3	43.3	0.0	26.9	26.9	0.0	33.2	34.1	-0.8	33
12	39.9	39.8	0.0	19.2	19.2	0.0	46.2	46.2	0.0	31.9	31.9	0.0	39.9	39.9	0.0	28
13	42.3	42.3	0.0	17.1	17.1	0.0	45.0	45.0	0.0	27.4	27.4	0.0	36.9	36.9	0.0	37
14	38.0	40.3	-2.2	17.6	17.6	0.0	44.2	46.3	-2.0	28.9	28.9	0.0	38.5	38.5	0.0	39
15	37.9	39.1	-1.2	18.6	19.5	-1.0	41.0	42.1	-1.1	27.7	27.7	0.0	27.2	32.6	-5.5	37
16	39.0	39.0	0.0	18.8	18.0	0.9	44.5	44.5	0.0	34.2	34.2	0.0	35.4	34.8	0.6	40
17	40.3	40.6	-0.3	14.9	15.2	-0.2	40.0	41.0	-1.0	19.1	20.2	-1.0	31.1	31.1	0.0	25
18	40.3	40.3	0.0	13.0	13.0	0.0	41.3	41.3	0.0	25.5	25.5	0.0	32.3	32.3	0.0	30
19	40.0	40.0	0.0	16.2	16.2	0.0	42.2	42.1	0.0	26.2	26.2	0.0	33.4	33.4	0.0	40
20	37.3	39.2	-1.9	15.5	15.5	0.0	44.1	45.7	-1.6	32.0	32.0	0.0	29.6	29.6	0.0	42
21	40.9	41.9	-1.0	17.7	17.8	0.0	43.9	44.7	-0.8	31.6	31.6	0.1	43.1	43.1	0.0	31
22	42.8	42.8	0.0	17.0	17.0	0.0	44.3	44.3	0.0	28.3	28.3	0.0	40.3	40.3	0.0	31
23	39.3	40.6	-1.3	12.5	12.7	-0.2	47.7	44.3	3.4	36.6	31.5	5.2	30.7	30.7	0.0	23
24	39.9	39.9	0.0	16.8	16.8	0.0	44.0	44.0	0.0	27.2	27.2	0.0	33.7	33.7	0.0	37
25	40.7	42.0	-1.3	18.0	18.0	0.0	49.1	49.6	-0.5	35.8	35.8	0.0	36.9	36.9	0.0	38

Table 3-6 unmodified and modified measurements with the value difference calculated

3.12.4 Data analysis – Descriptive statistics of the participants scan data (Activity 19)

As mentioned previously, the samples differed in size therefore the independent variables of age, body shape and BMI (as shown in *Table 3-7*) were quantified as a percentage as this made it easier to compare them.

The independent variables associated with age-related body shape change
Age
Value difference between the height and girth body measurement of unmodified and modified scans
Body shape
BMI

Table 3-7 Independent variables selected for descriptive statistical calculation

3.12.5 Data analysis – Welch's t-test (the t-test) (Activity 19)

Inferential testing came at the end of the SLVM process (*Figure 3-1, Table 3-2*: Activity 19). There are several inferential statistical tests, which could have been applied to this research. However, the most common approach to testing the null hypothesis is to examine and compare the means and standard deviations of each set of data. The t-test is the most appropriate formula to use for this methodology as it questions whether a difference in values between two group's (either independent or dependant) mean scores is unlikely to have occurred because of random chance within the sample (Coolidge, 2013). The data collected for this thesis was independent in that different age groups were scanned and the difference between the unmodified and modified data (the value difference scores) could be compared between the different age clusters. Comparing the value difference scores using a t-test provided a P value (probability value). According to Coolidge (2013) the P value evaluates how well the sample data supports the alternative hypothesis and its numerical value can confirm if the null hypothesis is true. So the higher the P value the more likely the null hypothesis is true and conversely the lower the P value the more likely the null hypothesis will be rejected (Coolidge, 2013). As the hypothesis for this thesis was directional in nature (3.6) a one tailed t-test was chosen. The one tailed t-test is normally used when hypothesis is deemed directional in nature as it is more robust than that of the two-tailed t-test (Cohen *et al,* 2011). The Welch's t-test two sample assuming unequal variance was used as the sample size of each age cluster varied and

Welch's t-test (from this point on referred to as the t-test) does not assume equal variance between sample sets (Albright, 2017). This is also confirmed by Blaikie (2003) who states comparable sample sizes between data sets is not necessary to undertake the Welch's t-test. In addition, Blaikie (2003) confirms the larger the sample the less need there is for normal distribution around the mean providing another reason for using this particular calculation as it was noted that some data sets may be skewed due some outliners in the measurement values when moving the landmarks.

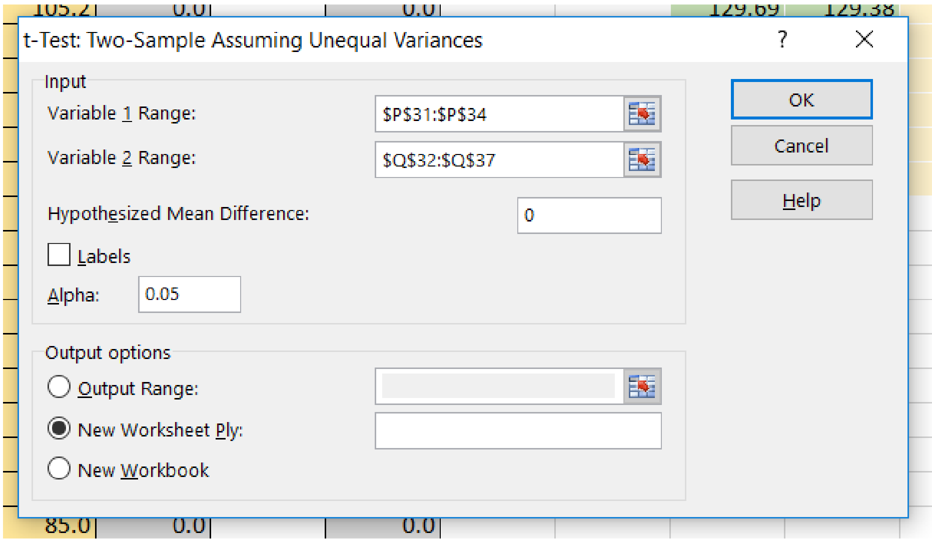


Figure 3-12 Excels dialogue box to input the data arrays, hypothesised mean and alpha value

The t-test was calculated within Excel as its data analysis tool add-in facilitates this calculation. *Figure 3-12* illustrates that the level of significance was set at alpha 0.05 (5%) as this is the most common value used for this test (Cohen *et al*, 2011, Coolidge, 2013). The variance of each data set was unknown and therefore a t-test – two sample assuming unequal variances was chosen from the Excel t-test drop down menu, and the mean value was set a 0 as the null hypothesis implies there is no difference in the mean between the two data sets (*Figure 3-12*). The results were presented in a tabulated format and discussed in the next chapter.

3.12.6 Data analysis - second process involving the Comparison of Demographics and the Variables which can Effect Landmarking Accuracy (CDVELA) (Activity 18)

Whereas the SLVM process was a collaboration involving this research, the CDVELA process was developed solely by this research for this thesis. The process was necessary as the hypothesis can only provide an indication of probability but does not explore possible causes. The CDVELA was deployed after the t-test (*Figure 3-1, Table 3-2*: Activity 18) as it explores possible causes of landmarking/body measurement error as well as providing the opportunity for participant engagement within the non-contact anthropometric process which can eliminate landmark and body measurement error. Providing this simple process gives new and existing users of the technology within the clothing industry a means of achieving accurate body measurements for pattern development, as the process requires no complex statistical analysis or writing of computer code but draws on the skills already present for the discipline of clothing product development.

The CDVELA uses the areas of Body Mass Index (here after BMI), posture, waist definition, age and body shape to examine 3D body scans for accuracy and facilitates the diagnosis of error. It is developed for the clothing practitioner as a new tool to be used during the scan data evaluation post-scanning event.

The CDVELA process involved a more in-depth analysis of each scan image to satisfy Objective [3], which required comparative analysis (both qualitative and quantitative) of the entire sample (all ages) to determine the reasons behind scanner landmarking error. The CDVELA process first involved observation of the pre and post SLVM scan images and secondly an experimental phase in which the independent variable of age related body shape change was compared against the dependant variable of scanner landmarking accuracy. The participant's scans were saved as both unmodified and modified scan files, the two were compared, and their visual and numerical changes documented. Observations and resultant actions were document within a new Excel spreadsheet (Appendix R). Following this descriptive statistical calculations of the categories of sample ages, BMI, body shape, average age and body measurements before and after scan data validation were undertaken to show the quantitative changes for each data set (demographic). Inferential statistical testing was then undertaken to either prove or disprove the null hypothesis. Inferential statistics infer the probability that an observed difference between groups is a dependable one or one that might have happened by chance (Coolidge, 2013; Blaikie, 2003). Put simply, it is a means of drawing conclusions about the entire sample using analysis of the central tendency (in this research it is the mean). The statistical tests will be elaborated further on in this section as they occurred after the visual evaluation of the scan data.

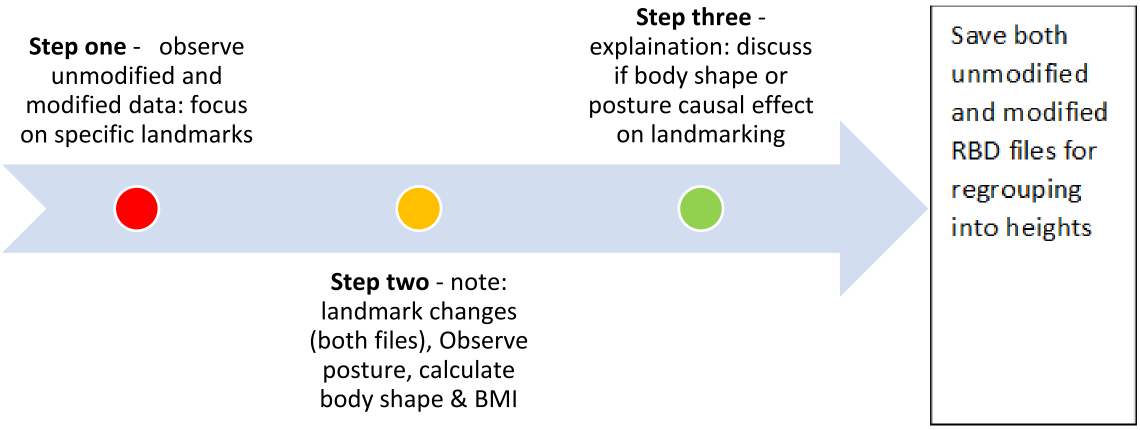


Figure 3-13 The steps of the CDVELA process (Activity 18)

3.12.7 Data analysis – CDVELA process observation and participant required amendment of each scan (Activity 18)

Scans were re-opened and viewed in an RBD format. This TC² file format forms the body model (Shi *et al*, 2006) and it is flexible enough to allow the image to be viewed either as a point cloud (*Figure 3-14*) or closed surface. The same 03_4cm_tolerance MEP file was used to landmark and extract body measurments.

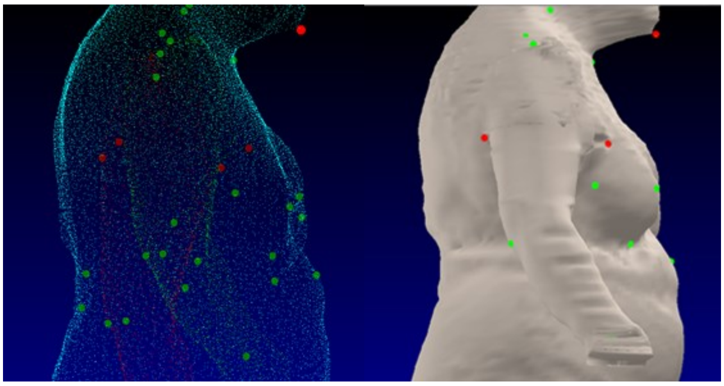


Figure 3-14 Point cloud and closed surface views

The TC² software allowed for body segments to be readily identified and/or excluded as required. As the point cloud of the torso is coloured blue the software allows this area to be isolated from the limbs and sliced for visual analysis (Figure 3-15).

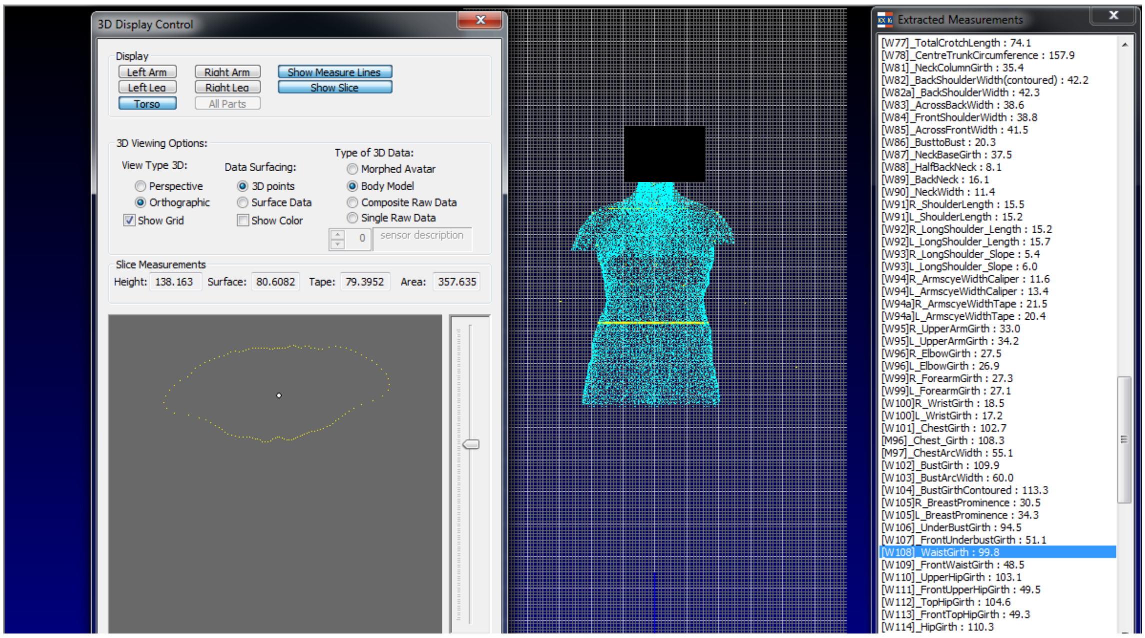


Figure 3-15 Isolate body region and slice function

The CDVELA process also allowed variables such as age, Body Mass Index (BMI), body shape or altered posture to be identified and established as the potential cause of landmarking error. Information surrounding these variables were documented using Excel (Appendix R). This research was seeking patterns in the variables between each age clusters to ascertain if one or more variables were responsible for landmarking error. An example of this would be if a 50% of particular age cluster manifested incorrect landmarking of the bust point, 52% demonstrated a top hourglass body shape and 65% where established as being in the overweight BMI category. This quantitative data was used to support the observational (qualitative) data recorded in the CDVELA notes (Appendix R).

3.12.8 <u>Data analysis - calculation of BMI (Activity 18)</u>

Participants from each age cluster had their BMI calculated. NHS.UK (2014) states that BMI is a measure that adults can utilise to check if they are a healthy weight for their height. Lee *et al* (2014), Ley *et al* (2007) and Barnes (2014), all studies related to or utilising body measurement practice use BMI scoring as a means of categorising their samples into body types to explain particular phenomena. BMI was coloured coded by this research so it was easy to ascertain at a glance the most predominate category from each age cluster. BMI scores are as follows:

BMI Score	Category
18.4 and below	Underweight
18.5-25	Normal weight
25.1-30	Overweight
30.1 - 40	Obese
40.1 and over	Very obese

Table 3-8 BMI scores, categories and colour coding, source: NHS.UK (2014)

This research shared similarities to Lee *et al* (2014), Ley *et al* (2007) and Barnes (2014) in that its focus was an older demographic and accordingly adopted this calculation to enable further categorisation of the different age clusters.

$$BMI\ is\ calculated\ as\ thus: \qquad BMI = \frac{weight\ (kg)}{height^2(m^2)}$$

Table 3-9 How to calculate BMI

3.12.9 Data analysis - posture assessment for extremes of posture

Altered posture was also noted as this had the potential to impact on both scan and landmarking accuracy. A grid of known dimensions was placed behind the scanned image on individuals who display visually apparent altered posture (*Figure 3-16*) and their posture was ascertained using Liechty *et al's* (2009) postural guide (*Figure 3-17*) and noted in the CDVELA notes if needed. The posture was not appended with any values, it was purely observed and categorised using Liechty's (2009) guide. Liechty's (2009) guide was chosen as it is familiar to clothing practitioners and is seen by this research as being an essential resource for individuals not familiar with different postures yet having to provide clothing that will fit them.

A participant's scanned image was placed side on, leaving both arms and legs visible as their placement when compared to other portions of the body can give visual clues to posture (*Figure 3-16*). Posture was identified by using the angles of the cervical, thoracic and lumber regions of the spine and a yellow line traced the angle. These were then compared to the visuals (*Figure 3-17*).

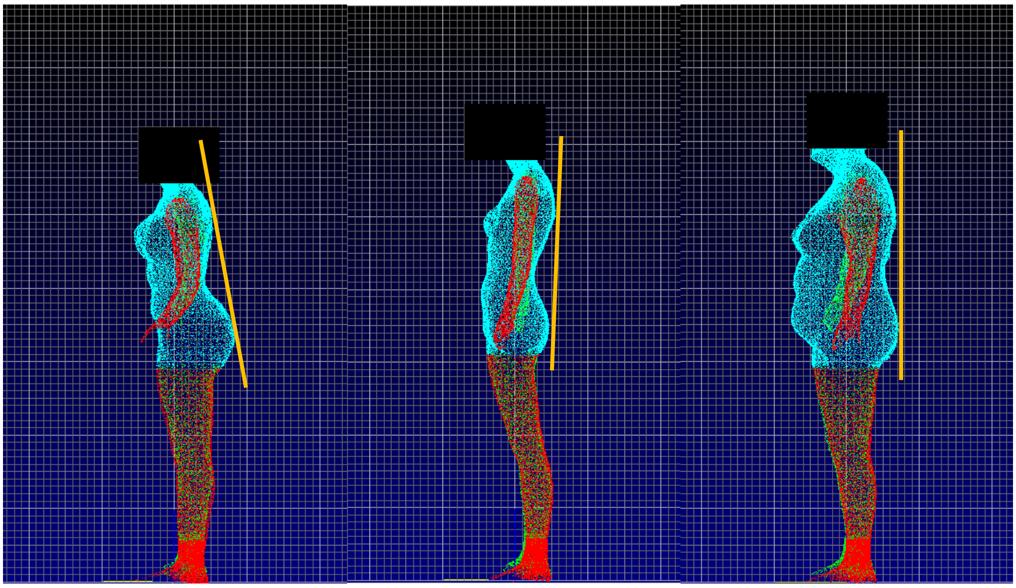


Figure 3-16 Grid to help ascertain posture

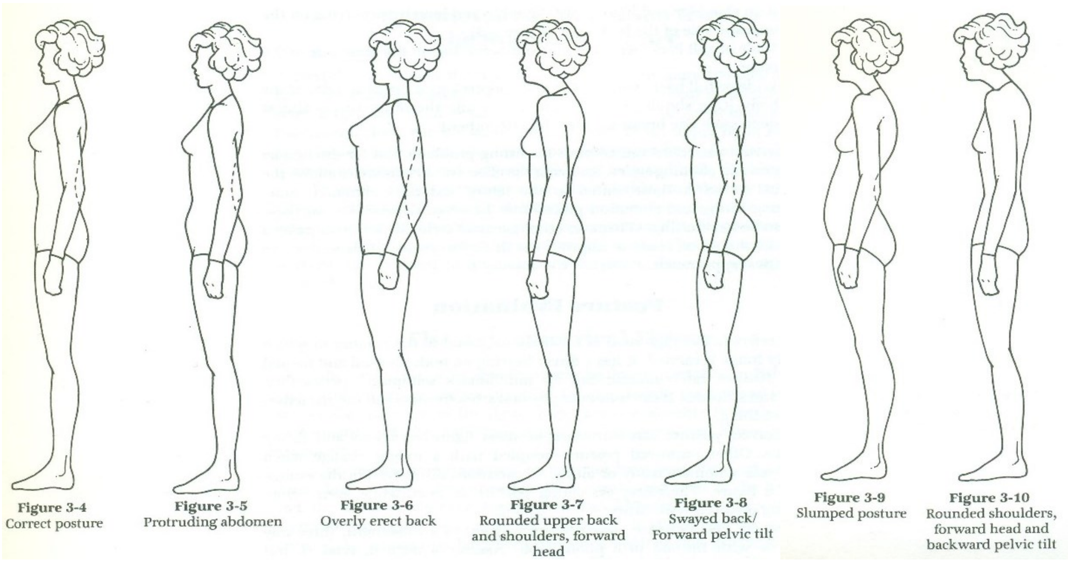


Figure 3-17 Source: Liechty et al's (2009) posture guidance

3.12.10 <u>Data analysis - categorising body shape (Activity 18)</u>

Mature women typically display a rectangular body shape (2.5) meaning the waist area can be less defined and therefore more difficult for the scanner to locate and landmark accurately. To determine whether landmarking error was associated with any particular body type, each participant's body shape was calculated and classified using Lee *et al's* (2007) method of female body shape categorisation (FFIT). Lee *et al's* (2007) method was developed using the definitions, female fit identification technique and validation studies developed in the work of both Simmons (2002) and Devarajan and Istook (2004). Simmons (2002) work developed software which could be used in conjunction with 3D bodyscanning to represent women's' body shapes in a mathematical way. Simmons (2002) define those shapes as being:

Shape	Definition
Hourglass	There is a small difference in the comparison of bust to hips circumference, and the ratios of bust to waist and hips to waist are about equal (Simmons, 2002).
Bottom hourglass	The hip circumference is larger than the bust circumference and the bust to waist and hip to waist ratios are significant enough to produce a defined waistline (Simmons, 2002).
Top hourglass	The bust circumference is larger than the hip circumference and the rations of bust to waist and hips to waist are significant enough to produce a defined waistline (Simmons, 2002).
The spoon	There is a larger difference in the circumference of the hips and bust. The bust to waist ratio is lower than that of the hourglass and the high hip to waist ratio is greater (Simmons, 2002).
Rectangle	Bust and hip circumferences are fairly equal, and the ratios of bust to waist and hip to waist are low. This shape does not have a clearly discernible waist (Simmons 2002)
Diamond	The average of the stomach, waist and abdomen circumferences are more than the bust circumference. The shape shows corpulence in the form of excess flesh rolls which protrude at the waist area.
Oval	The average circumference measurements of the stomach waist and abdomen are less than the bust circumference. This shape is disenable when a participant is viewed side on in profile (Simmons, 2002).
Triangle	The hip circumference is larger than the bust circumference and the ratio of bust to waist is low. This shape has large hips when compared

	to the bust and no discernible waistline (Simmons, 2002).
Inverted triangle	This shape has a large bust circumference than hip circumference and the ratio of bust to waist would be low (Simmons, 2002).

Table 3-10 Definitions of nine body shape from the female figure identification technique, Sources: Simmons, (2002) and Devarajan and Istook, (2004)

Devarajan and Istook (2004) then tested the software using larger sample of 253 participants to validate the technique that ensures it suitability for use in other studies such as this research. Using the work of Simmons (2002), Devarajan and Istook, (2004) and Lee *et al* (2007) three academics from the University developed the body shape formulas in Excel (Appendix S) which provided the means to calculate any of the nine shapes using each individual's bust, waist, high and low hip circumferences. These academics granted permission for this study to use it. The entire samples body shape classification was documented in Excel using the key dimensions to calculate body shape, shape name and colour coding each cell (Appendix S). Colour coding was used for two reasons, the first being recurring body shapes could be seen at a glance of the spreadsheet. The second reasons was dealing with large amounts both written and numerical data can be challenging when the time comes to analyse and reduce the data. This study had gathered large amounts of both data types and so in the spirit of the mixed methods approach a formula was developed in Excel, which would count each coloured cell (*Figure 3-18*) and provide a means for simple statistical analysis. This process established if particular body shape dominated each demographic group, and quickly showed any prevailing shapes. The oval, spoon and diamond are not present below and the reasons for this will be discussed in the results and discussion chapter.

rectangle	bottom hourglass	hourglass	triangle
top hourglass			

Figure 3-18 Colour coding each body shape

3.12.11 Data analysis – the questionnaire responses on fit issues, garment fit/preference and favoured retailers (both qualitative and quantitative) (Activities 13, 14 and 18)

This section of the methodology chapter again uses a questionnaire (survey) methodology to gather its data which if structured correctly can collect both qualitative and quantitative data (Plowright, 2011). It also used mixed methods, content analysis and descriptive statistics, in the course of it data analysis.

The questionnaires contained information which could identify the participant and match them to their scan. This was so their selected waist position could be compared and modified if needed during the CDVELA process. This meant that the questionnaires were not anonymous and are therefore the content of the questionnaire needed anonymisation which this research did (see Appendix AE). Content analysis and open coding of each open-ended questions was manual and took place after the responses from each questionnaire had been transcribed into a table.

The responses from the questionnaire were presented mainly in a graphical or tabulated format as the questionnaire methodology allows for this type of data analysis and presentation to be undertaken. Descriptive statistics were used as they more concisely described the results of the data giving insights into the women's perceptions of garment fit, retailer preference and waist positioning. This meant that the content of the responses to open ended questions was analysed by reading and re reading the questionnaire and open coding for themes and these themes were then counted/quantified so percentages could be calculated, frequencies could be established and the results shown in a chart or tabular format. The decision was taken to quantify the results as a percentage as this made it easier to show the different responses proportionally thereby giving more context.

The number of completed questionnaires was compared to the sample number and this was calculated and presented graphically in a pie chart alongside concise discussion, which indicated the best method of questionnaire delivery (the questionnaire were either distributed on the day of scanning or emailed to the participant after the event). The chart and discussion would indicate how successful the uptake of the questionnaire was which could provide helpful information for comparable studies.

Average age and age range of participants completing the questionnaire was also calculated and show in a column chart as this would show which age group engaged more with the questionnaire and give a context to the responses.

Garment preferences and garment comfort were established and the findings were calculated as a percentage and shown as a table and as a pie chart graphic. Participants were required to give expanded answers as to why they found particular garments comfortable. This was again shown as a percentage of the sample total. In addition, because the answers were rich in information, content analysis of each participant's response was also undertaken to reduce the data into reoccurring perceptions and themes, the results of which were modelled into a visual to demonstrate what the participants perceived as the most important factors regarding fit. Content analysis is defined as 'the systematic observation and quantitative description of the manifest content of communication' (Zikmund *et al,* 2013). Content analysis facilitates the classification, tabulation, and evaluation of key themes and symbols to ascertain meanings and probable effects (Krippendorff, 2004) and so was deemed suitable by this thesis.

Reported garment fit issues and areas of the body where garments do not fit correctly were quantitatively analysed as the question was structured to be closed and possible answers were pre-determined allowing the participant to select the one which best fitted their experience. These predetermined responses were counted and their frequency was shown using column charts.

Questions which asks the reasons for poor fit were open ended. Therefore the responses to this question came in the form of expanded answers which was again rich in information. Therefore this information was analysed using content analysis to open code and establish a pattern of themes. Open coding does not allocate categories, classifications or themes pre-data collection as these are normally developed during data reduction and analysis (Plowright, 2011). This condensed the responses into themes that were interpreted as short statements. Responses that best fitted the short statement, such as the response may contain words from the short statement or the meaning might match the short statement were collated under each short statement. The short statements were then counted and their frequency shown in a bar chart to illustrate the most common statements.

This thesis wanted to establish if there were any reoccurring fit issues for this demographic. This question was posed as open-ended question and once more, the responses provided rich information which needed content analysis to establish reoccurring themes and meanings. Once undertaken positive and negative responses concerning the samples perceptions of garment fit were counted and calculated as a percentage of the whole sample. These percentages were presented in a pie chart format.

Participant's responses for retailer preference was tabulated. Each retailer was given a column and the amount of times that retailers was selected by a participant as a favoured retailer was counted. This information provided the thesis with insights into the most popular retailers. It also provided an initial list of retailers for the measurement guidance survey undertaken by this thesis for Objective [4].

3.12.12 Data analysis - modifying the waist landmark on the 55+ sample using the responses of the visual aid (Activities 14 and 18)

The final part of the CDVELA process involved a visual assessment by the participants of the waist landmark for 52 of the 80 scans within the mature female sample (55+). Using the visual aid within the questionnaire (3.9.9), fifty-two women identified where they believed their waist to be for clothing purposes (*Table 3-2*: Activity 14 and 18).

Following the feedback from the mature female participants regarding the placement of their waists, the modified scan files that had already been through the SVLM were revisited within the CDVELA process (Appendix R). Using the definitions culled from literature (*Table 3-5*) and the visual aid (*Figure 3-5*), the landmark on the centre back of the waist was moved to align with the participant's choice. As the front and side waist landmarks were linked to the centre back of the waist moving this landmark ensured the other waist landmarks moved the same distance with it. Any scan which required modification of the waist landmark due to participant feedback was noted in the Excel spreadsheet to determine whether the participants favoured a particular waist definition/position or whether particular body shapes caused the 3D-bodyscanner to place the waist in a particular place. Simple statistical analysis of the participant responses was undertaken to establish the most popular waist position for clothing.

The original and amended scans were saved and both were batch processed into an Excel sheet so that original and amended dimensions of waist height from floor could be compared. These dimensions were then subtracted from each other to provide a numerical value to indicate how much the landmark had moved in a vertical plane. This research termed this new value as ‘the waist height difference’ (here after WHD). Body shape was also checked for correlation against the WHD to identify whether any particular body shape was prone to large positive or negative WHD readings.

3.12.13 Data analysis – presenting the findings of the WHD (Activity 18)

Each WHD value was collated in Excel and the frequency and dispersion of these values were counted and placed in a graph to show how far away the waist position had moved after the technician had modified the waist landmark. These values were noted as either negative or positive. In addition the coefficient variance (here after CV) was calculated by establishing the mean value and standard deviations of the WHD. The standard deviation was then divided by the mean and multiplied by 100 to give the CV a percentage value. Coefficient variance (which is also termed relative standard deviation) gives a standardised measure of the dispersion of a frequency distribution and as it is unit-less it can be used to compare data sets that have different units or names (Coolidge, 2013). The WHD chart in this thesis showed the frequency of body shape (a name) and WHD values (numbers) and therefore the CV was appropriate in this instance.

3.13 Re-grouping the three demographic samples for pattern development: testing both SLVM the CDVELA processes using pattern construction Objective [3]

3.13.1 Introduction

Both the SLVM (Activity 17) and CDVELA (Activity 18) processes were developed as a means of evaluating, correcting scan landmark/image error and diagnosing possible cause. Both processes relied on the skill and knowledge of the technician when evaluating scans and modifying landmark position which can be a subjective process. Therefore, this research decided on a course of further validation of each process using pattern development and toile fitting to determine the accuracy of the amended landmarks.

3.13.2 Using the clothing pattern as a test instrument (Activity 27)

Numerous high profile surveys have been undertaken by the clothing industry using scanning technology (2.6), with many choosing to use the TC^2 3D bodyscanner as their survey instrument (Appendix A). It is to be expected that these body measurements will inform clothing pattern generation, resulting in a garment that will fit comfortably and present the body in a pleasing way. For that reason, this research decided the next step (as part of Objective [3]) was to examine further both sets of body measurements from unmodified and modified scans using bodice pattern development as the test instrument.

Additionally, it also wanted to assess how participant engagement (3.9.8) affected the geometry of the pattern shape, and if this shape altered participant perceptions in terms of comfort and aesthetics.

3.14 The process for selecting women from each age cluster for pattern construction (Activity 27 and 28)

3.14.1 Height (Activity 27)

All three age clusters were mixed together into new groupings. Height was chosen to create these new groups (Appendix T), as it is generally an accurate predictor of other vertical measurements (O'Brien & Shelton, 1941, Winks; 1997). It has already been established that height can change as a women ages (2.3.1), however the research undertook a synchronic analysis – a snapshot in time, if you will - using heights as a criterion rather than attempt a diachronic analysis which would involve speculation of the previous height of each older participant.

Each height group/cluster had to contain a mixture of each of the chosen demographics for comparison. The heights varied greatly which meant groupings had a ±8cm tolerance to insure all ages could be clustered successfully (Table 3-11 Height Clusters).

Height clusters
142cm-149.9cm
150-155.5cm
156cm-159.9cm
160-165cm
165.1-168.7cm
168.8-174.5
174.6-178.7cm
178.8cm-183.5cm

Table 3-11 Height Clusters

3.14.2 Two or more scan modifications (Activity 27)

Scans that had (after both the SLVM and CDVELA processes) received two or more modifications were selected from a height cluster. Pattern geometry may change after each modification and this research wanted to ascertain how numerous modifications (two or more) would impact on the geometry of the pattern in terms of length, girth and angle change.

3.14.3 Rationale and final sample number of 9 women selected to have their patterns constructed (Activity 27)

A criteria for selecting suitable scans for pattern development was devised *Table 3-12.* The criteria ensured that a participant's scan data from each age cluster was chosen so that the pattern geometry could be observed for different ages. The participants would share similar over all height so differences in segment heights for key measurement areas like the bust for each age could be observed using the pattern. The scan data had to have complete measurements for bodice block development to use for pattern generation both within the unmodified and modified scan data as any scans with missing measurements meant that the both patterns per participant could not be produced. With this in mind, the chosen scans had to have had two or more landmark modifications so the results of modification could be seen within the geometry of the pattern. Finally the patterns developed from unmodified and modified scan data for the 55+ demographic would be made into a toile so these participants could try the garments on and comment on their fit. Therefore the criteria stipulated that the three participants selected from the 55+ demographic had to agree to a fitting and be within a close proximity and easily available for the fitting to take place.

As a result of this criteria *Table 3-12* the participant numbers were was reduced to 9 participant's (3 from each age cluster *Table 3-11*). This thesis had to be mindful of the time it would take for pattern drafting (there were 18 patterns to draft in total) as there was not an infinite amount of time particularly as scan data collection had taken a large portion of the research time. Therefore it was also considered sensible to have only 9 participants rather than the entire sample (all age clusters) to draft patterns for as this was achievable in the time frame of 2 weeks.

1	Each group needed to contain a participant from each of the demographics (18-25; 35-45; 55+) to address Objective [3].
2	Each person should share a similar height.
3	Each scan should show all valid measurements for a bodice pattern in both the unmodified and modified versions.
4	Each participant's scan needed to have two or more landmark modifications, as this would demonstrate the scanner had some difficulties in placing landmarks accurately at some stage.
5	Consent, availability and proximity for toile fitting for the 3 women from the 55+ sample only.

Table 3-12 The criteria used to select participants scan data for pattern development

3.14.4 Chosen pattern development method (Activity 27)

A simple bodice pattern covers the areas of the torso prone to age-related morphological change. Therefore the measurements use to develop a bodice block would be the data needed to evaluate how much change in dimension there is between older and younger women. Beazley and Bond's (2003) pattern construction guidance was chosen (*Table 3-2*:

Activity 27) for its method and body measurements. Other pattern construction literature (3.3) was critically analysed and rejected as being either dated in the block shaping, having unclear measurement guidance, using none metric measurements or containing too many derived (proportional) pattern measurements. Beazley and Bond's (2003) textbook guidance was seen as ideal as it is further supported by Beazley's (1997) earlier research paper which concerned procedures in undertaking a survey of body measurements. Perhaps more importantly its method facilitated a more direct method of drafting with only the neck circumference requiring a proportional calculation. Its method also facilitated depth measurements from the side neck point to the bust prominence and bust prominence to waist. This is an important set of measurements for block development for an older female demographic as age-related body morphology change can increase the bust girth making the breast larger and heavier and as a result a lower bust point. The bust point is more accurately placed using a combination of both measurements.

Gill and Chadwick's (2009) research paper into the determination of ease allowances into pattern construction was also consulted as their research focused on the analysis of five construction methods for women's bodice and sleeve blocks using anthropometric measurements from a common size specification. Portions of their methodology in terms of measurement nomenclature and definition were utilised by this study to understand how measurements provided by Beazley and Bond's (2003) method then maybe matched against those produced by the bodyscanner's software.

Beazley and Bond's (2003) method listed 3 girth measurements, 5 height measurements and 5 width measurements as being necessary for their bodice block development (Appendix U). The 03_4cm_tolerance MEP was employed to extract body measurement for bodice block generation initially; as it had previously been developed for clothing purposes (Sizemic, 2010). Unmodified and modified scans from each demographic were batch processed.

It was assumed that the Beazley and Bond (2003) bodice measurements could be isolated and copied from the batch processed spreadsheet which contained all the measurement provided by the 03_4cm_tolerance MEP file as the measurements within this file were similar to those of SizeUK which was designed for clothing purposes (3.9.4, Appendix V, 3.11.3). However, upon scrutiny of all the measurements within this MEP file it became clear that it did not contain equivalent measurements for the armscye depth or side neck point to waist traversing the prominence of the bust. Therefore, these measurement definitions had to be written into the software using the edit MEP facility Appendix Q). These two new measurements were developed with the assistance of an academic from the University of Manchester who was expert in writing algorithms specifically for the TC² database interface. As this MEP contained two additional measurements it was titled 03-MMU-V5-SG-Scyedepth.mep. This MEP was used batch process the scans of each demographic into a new Excel spreadsheet containing only body measurements for Beazley and Bonds (2003) bodice pattern (Appendix Appendix V).

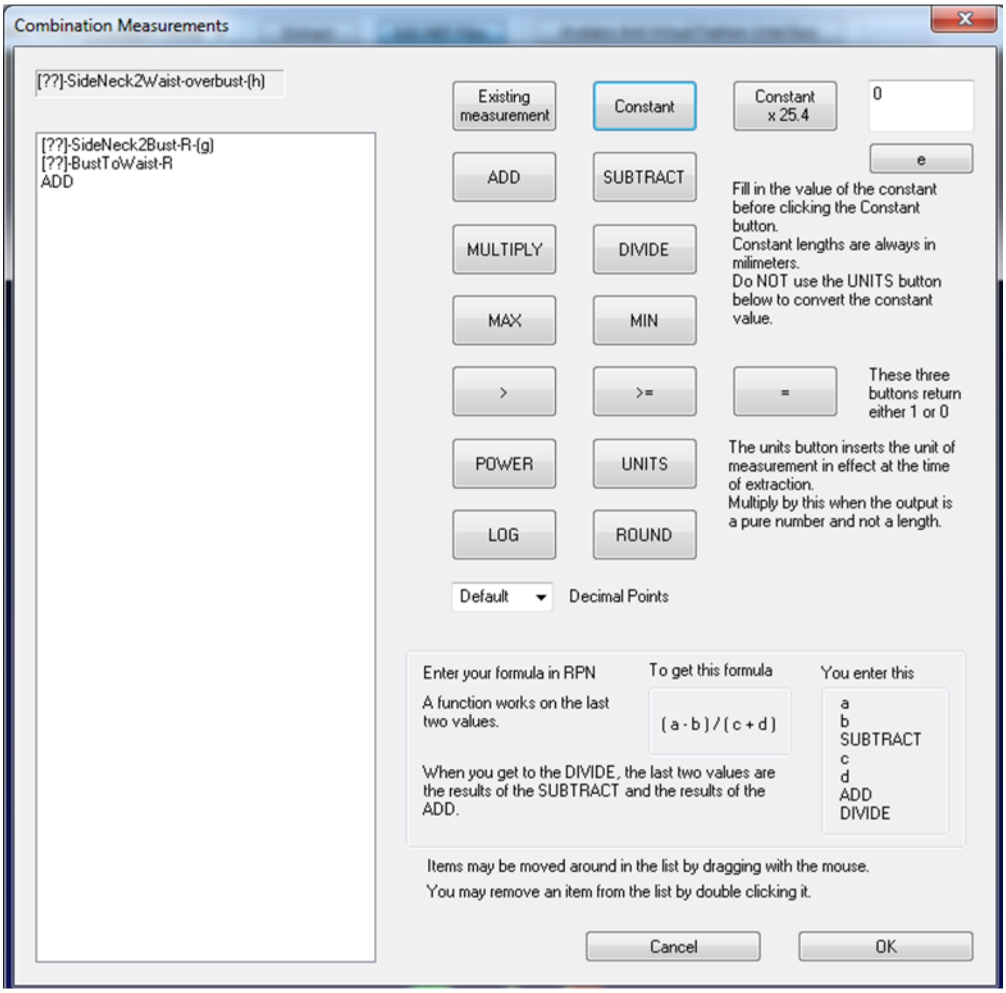


Figure 3-19 Edit MEP facility – using a combination of measurement definitions

The entire sample of scans (both modified and unmodified) were now reduced to bodice measurements only (Appendix V, *Figure 3-1*, *Table 3-2*: Activity 28). As stated previously, nine participants were selected from the entire sample for bodice pattern construction and their measurement were isolated and placed in a new spreadsheet (Appendix V). From this information 18 patterns were drafted, one pattern using unmodified and one the modified scan measurements.

Table 3-13 Scans selected for pattern construction

55+	18-35	35-45	Groupings
65	25	36	height group from 153-153.5
55	23	35	height grouping from 165.1-166.5
70	23	43	height grouping all 165

3.15 Pattern drafting

3.15.1 Manual drafting

All the patterns were drafted using manual methods by the author of this thesis. The rationale for this was manual pattern drafting enabled the patterns to be constructed to the actual scale and proportion of each participant thereby making the pattern practitioner more familiar with the required dimensions of each pattern piece. CAD pattern drafting methods cannot easily enable this as the pattern pieces need to be small enough to be viewed in their entirety on a computer screen, making them more abstracted even to an experienced pattern construction practitioner.

The pattern equipment used consisted of a plastic setsquare, flexible tape measure, metal metre ruler, French curve, mechanical HB pencil, eraser, masking tape, pattern weights and pattern paper.

All patterns followed the Beazley and Bond (2003) step-by-step method for a fitted bodice as outlined in their textbook which ensures the back and front bodice halves are constructed to together within a rectangle of pre-determined dimensions based on the measurements of an individual's nape to waist and half bust girth plus ease. This method also provides a clear visual of the armhole, an area that, according to Richards (1981), may need increased ease allowance to provide a comfortable fit for some mature women.

Patterns were mapped onto the paper (*Figure 3-20* and *Figure 3-21*) and then each seam and dart were trued to ensure the lines of the pattern correctly fitted together and were properly balanced (*Figure 3-21*). Unmodified and modified scan data patterns for each participant were drafted side-by-side to enable an immediate visual comparison of shape and values. Seam allowance was not added at this stage.

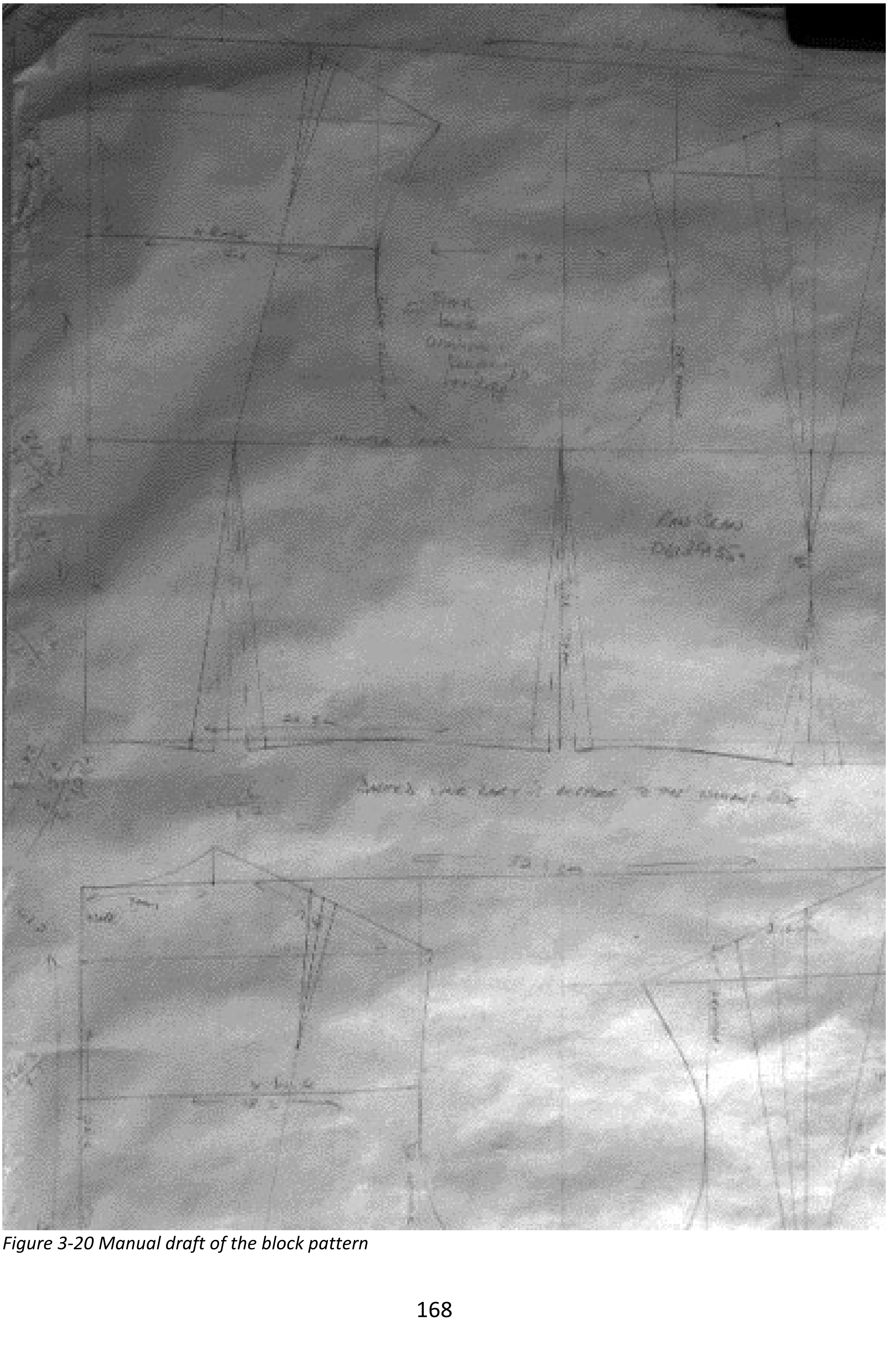


Figure 3-20 Manual draft of the block pattern

Figure 3-21 Manuel truing

3.15.2 Pattern validation

The manual patterns were checked for accuracy against the method by an academic with 35+ years' experience in pattern construction and garment fitting who works as a senior lecturer at Manchester Metropolitan University. They also gave critical feedback on pattern geometry and Beazley and Bond's (2003) method. Their comments were recorded into an Excel spreadsheet (Appendix W).

3.15.3 Digitising the pattern pieces

Following pattern validation all the patterns were digitised by the author of this thesis into the Gerber pattern drafting system, available within the university. They were manually digitised as this meant the resulting pattern file is a vector image and therefore its dimensions are more faithful to the original pattern. All front and back pattern pieces were labelled with the scan code prefixed by either U or M to show if the pattern used unmodified or modified data. Digitising ensured there were copies of the originals, and the digital images enabled pattern pieces to be overlaid on top of each other so the geometry of the unmodified and modified patterns could be visually determined as well as providing insight into how patterns from different ages or body shape appear when realised. Finally, the front bodice patterns were mirrored to create a full front bodice; and a 1cm seam allowance was added on to the sides, and shoulders. The centre back edges of the patterns had a 2cm seam allowance to allow for a zip.

3.16 Fit sessions for the 55+ patterns

3.16.1 Rational for fitting the toiles

This portion of the study wanted to explore how the patterns fitted the three women chosen from the 55+ sample, in terms of observed fit by a clothing practitioner compared to the perception of fit by the participant wearing the garment (*Figure 3-1, Table 3-2*: Activity 29). This was the point where participant input and engagement within the scanning process (via the questionnaire and visual aid) could be tested to judge if it worked and if it could then be used in further scanning surveys. It also tested the effectiveness of landmark modification within the SLVM.

3.16.2 Toiling each pattern (Activity 29)

Both sets of patterns for each participant were cut in calico that had been pressed using steam beforehand to both relax and pre-shrink the cloth. These were lock-stitched together and an open-ended plastic toothed zip was lock stitched in the centre back seam so the toile could be easily donned. The zip was placed on the centre back as zips are normally placed in discreet areas of a garment such as back or side, and this research did not want the participant's attention detracted by a zip down the front of the garment.

The pattern name was marked discreetly on each toile to distinguish which was the unmodified and modified garments. Each toile was pressed once sewing was complete. The author of this thesis undertook all of this work.

3.16.3 The fit session (Activity 30)

Participants were contacted by phone, asked if they would like to fit on the toiles from their scans and if they agreed the fit process was explained to them. They were asked to wear their own lingerie and ensure they wore either a skirt or trousers as they would be required to try a top on.

The fit sessions were carried out in a place of the participants choosing which was required to be private and have a mirror. Participants were asked to sign a consent form to allow their feedback and images to be used for this research (Appendix X). Documentation was developed to collect participant's feedback regarding the fit of each bodice, and to also record which bodice they preferred (Appendix Y). This documentation was completed by the person observing the fitting process. The bodices were fitted in no particular order and the participant was not made aware that there was any difference between either one. The participant fitted each of the two toiles in private room and were asked to join the fit observer in another room to view themselves in a mirror and to allow the observer to collect their thoughts and reactions of each toile on a pro forma. Grogan *et al* (2013) used a similar approach in that participants fitted a dress of their choice and provided feedback on its comfort and aesthetic whilst viewing themselves in a mirror. The point of difference between this study and Grogan *et al's* (2013) is that the toiles that were fitted were custom made and were basic in their aesthetic.

An observer with 25 years' worth of pattern amendment and garment fit assessment who works as a senior lecturer at Manchester Metropolitan University was chosen to observe and provide comments on the fittings. The observer also viewed the toile and made notes on its fit separately using the principles of fit as first outlined in Erwin and Kinchen's (1969) textbook, Clothing for Moderns. The author of this thesis was present at the fittings. They state the elements of line, ease, set, balance and grain need to be in equilibrium with body dimensions to achieve good fit. Both toiles were photographed on the participant from the front back and side for further observational analysis after the event (Appendix Z).

Once the fitting was complete, the participant was given paper copies of both bodice patterns as a thank you.

3.17 Establishing clothing industry requirements Objective [4] (Qualitative methods)

3.17.1 Introduction to Objective [4] and rationale for a survey of measurement guidance

This portion of the research also involved the accomplishment of Objective [4], which sought to establish industry requirements when applying landmarking definitions to current industry protocols for the improvement of fit analysis, garment sizing and garment fit. Objective [4] used two data collection methods – a survey and a case study (*Figure 3-1, Table 3-2*: Activities 21, 22, 23, 24 and 25).

Body measurement is the prerequisite to clothing construction (Beazley and Bond, 2003) and the literature review indicated that anthropometric guidance from academic sources could prove insufficient for women whose body morphology has moved away from what is considered standard (2.2). To commence Objective [4] it was determined that this research should gain a broader insight into the provision of anthropometric guidance provided by High Street retailers who directly target mature women as customers. Three quarters of Britons shop online (Canocchi, 2014) and over half of online sales are for clothing products (Brook-Carter & Parsons, 2014) which indicates many clothing retailers now have an online presence and that online clothing sales are rapidly increasing (Ter Haar, 2013). Clothing retailers who choose to sell online commonly provide consumers with facilities to help with garment size selection and the determination of their own body size. This normally appears in the form of a garment or body size chart and written/visual guidance on how to measure key dimensions such as the bust, waist and hips. This guidance helps consumers make sizing choices and in turn can influence a sale. Sales are important to retailers, and these facilities, to some degree govern customers purchasing intent (Daanen and Ter Haar*,* 2013). Therefore, this research sought to gather retailer's measurement guidance (*Figure 3-1, Table 3-2*: Activity 21) for a number of reasons. The first was to establish the key measurements retailers use to allow customers to select a garment size. The second was its knowledge of body morphology for the mature women aged 55+ via the landmark definitions it uses for its key measurements. The third was to familiarise this research with these landmark definitions prior to commencing the case study, and the four was to understand how women apply this measurement guidance (during the scanning questionnaire which uses the visual aid) in in the assessment of their own key measurement positions as women would not normally have access to a body scanner to check their body dimensions and would have to use manual techniques for this purpose.

Once the survey of measurement guidance was completed the research then progressed to a more in-depth case study approach whereby a large High Street retailer provided detailed information on their requirements from 3D bodyscanning technology and how this data is then used to inform or enhance their products.

3.17.2 Measurement guidance survey

The survey of measurement guidance began by returning to the earlier questionnaire (3.9.8, *Table 3-2*: Activity 13) which accompanied + 3D bodyscanning survey. Question 15 sought to establish favoured retailers (Appendix J). The participants provided a list of preferred retailers, some of which catered especially for mature women. From this list, a purposive sample of twenty-four UK women's clothing retailers were chosen on the basis that the retailer's target customer was a mature woman (Appendix K). Whilst searching for these retailers it became apartment that retailers catering for this demographic are plentiful, and to ensure a broader understanding of the measurement guidance available another 33 retailers were added to the list. This meant the overall total of retailers surveyed for their measurement guidance totalled 57.

Determining a list of retailers that cater for a mature demographic was not a straightforward task as many retailers, though aiming to target a mature female audience, use models which look physically younger. This is perhaps because they do not want to be seen as explicitly targeting an older female demographic as this deter mature women from purchasing (2.10.3). So the list of retailers for the measurement guidance survey were supplied by the women age 55+ who had filled in the questionnaire when they had been scanned.

In an effort to not rely solely on how old each model looked to determine if the retailers offer was targeted at a mature demographic other evaluation criteria had to be decided upon. Therefore, to determine which retailers mainly cater for mature women from the list of retailers provided by the scan participants, the following observations were used:

- Size charts did not contain exceptionally small sizes such as a size 4 or 6
- The models used to promote the garments looked mature
- The garments were styled or accessorised in a more classic manner

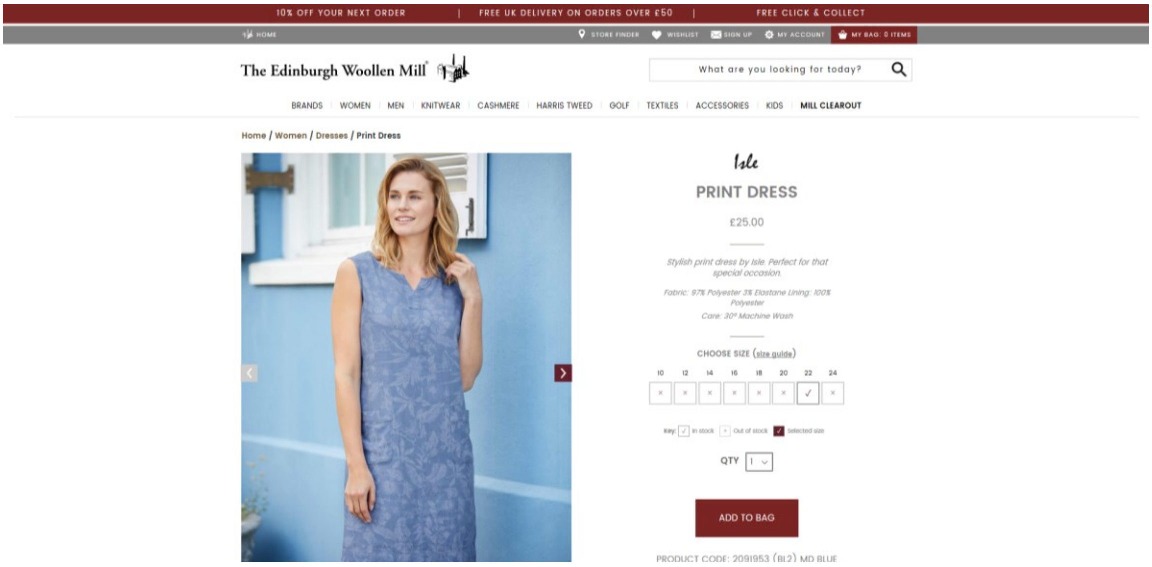


Figure 3-22 A mature looking model wearing a classically styled dress with a size chart that begins at a size 10 Source: Edinburgh Woollen Mill (2017)

Measurement guidance was collected where possible from online store sites and this data was reduced and tabulated as an easy method of collation, which also facilitated coding (Appendix K). The content of each measurement description and visual was evaluated and open coded using a template analysis approach (Appendix L). As stated previously in section 3.12.11, content analysis facilitated the classification, tabulation, and evaluation of key themes and symbols to ascertain meanings and probable effects (Krippendorff, 2004). Analysis of the content of each piece of measurement guidance was undertaken to establish the clarity of the guidance when compared to national anthropometric survey guidance – already collated for Objective [1] - surveys guidance, and the ease with which the measurements could be taken by an older woman. This analysis also indicated where the retailers expect certain landmarks to appear on the body and demonstrated if such guidance was informed be body or garment measurements. Once this complete the work progressed on to a case study approach as the survey of measurement guidance only provided one view of how clothing retailers use anthropometric guidance.

Now that both the SLVM and CDVELA processes had been undertaken for the Manchester and Leeds surveys this research wanted to establish how effective both processes could be when utilised for the clothing industry (*Figure 3-1, Table 3-2*: Activities 24 and 25). Bodyscanning technology has so far only been truly adopted by educational and governmental institutions (Aldrich, 2008) and published knowledge of its application within the clothing industry is scant (Gill *et al,* 2014b) therefore this research wanted to establish what the clothing industry would require from the technology and it also wanted to determine how it currently utilises anthropometric data. A case study methodology was decided to be the best method to establish this (*Figure 3-1, Table 3-2*: Activity 22).

3.17.3 Introduction and rational for Objective [4]

The purpose of this thesis is to improve garment fit for mature women using correct landmarking and non-contact anthropometric methods. These methods have been developed in an academic environment using the tactile knowledge gain through 18 years of working in the clothing industry. To see how effective they are in an industry setting required this thesis to test them in a real-life industry setting. Therefore for Objective [4] a case study approach was needed details of which will be explained and expanded upon within the next few sections of this chapter.

3.17.4 Clarifying the terms used in this section of the methodology

Interactions between the university and the company are outlined in this portion of the methodology. The following terms were used to describe the sample, case study, personnel undertaking the scanning event and the event itself:

- The sample case was termed the High Street retailer
- The High street retailer was termed the company
- The academics who partook in the scanning event were termed ‘the scanning team’
- The scanning event was termed ‘the scanning project’

The reasons for highlighting terms at this stage is to enable the reader to differentiate between the collaborative scanning project undertaken as part of the methodology and when the author refers to the thesis as the research or work which will ensure no confusion.

3.17.5 Rationale for a case study approach

This study has acknowledge that the UK clothing industry is appearing to address this issue by conducting different national anthropometric surveys using 3D body scanning technology to gather anthropometric data of its population (2.6). The largest UK anthropometric survey to date - the SizeUK survey – has put limited information in the public domain, so it was unclear how the scan outputs were landmarked, configured, validated and applied. What is also not clear is if the scan data was fully understood by the clothing practitioners, which gives purpose to this research. Therefore, to establish industry requirements when applying landmarking definitions to current industry protocols for the improvement of fit analysis, garment sizing and garment fit for Objective [4]. It was necessary to gather primary data of company practice ideally from a large UK High Street clothing retailer's that directly caters for mature women and one which the women who had previously been scanned had shopped with.

Interviews were, initially thought to be the best means of collecting this type of data as they enable the collection of more in-depth data rich in description from a representative sample of participants (Marshall, 1997). These participants – current industry practitioners - would be able to elaborate on their practice and the processes their company had in place to take body measurements and convert them into garment dimensions. However, it was decided that interviews could not provide an opportunity to view and actively be involved within the process of how a clothing company collects and applies anthropometric data to improve their products fit, which was required to conclude Objective [4]. Thus, a methodological approach that involved using a case study was developed and applied to this portion of the study.

3.17.6 Case study definition

Broadly speaking, a case study approach investigates a social phenomenon through analysis of an individual case (Kumar, 2005) using a variety of methodologies (Leedy and Ormrod, 2010), which followed the mixed method approach utilised throughout the methodological design of the study. Mixed methods are often associated with the worldview of pragmatism, which – as stated previously - this research determined as a starting point for the research design. Examining a case study provided insights as to how a typical High Street retailer employs anthropometric data using 3D body scanning technology within its product development process through the acquisition of written and observational and data.

3.17.7 Recruitment and sampling

The sample company for this study was not formally recruited. Meaning that they were not approached in the first instance to become involved in this study. The sample - a large UK online clothing retailer - contacted Hollings Faculty/Department of Apparel to express interest in doing some collaborative research using the University's TC^2 body scanner. Due to the University's previous involvement with the SizeUK survey and subsequent small scale 3D body scanning surveys thereafter, the it was gaining a reputation as an emerging centre for research surrounding this scanning technology and this perhaps explains how why the company - who incidentally had also previously participated in the SizeUK survey - contacted the university initially. The company was based in the North West and was one of the retailers whom this study's mature participants (from both Manchester and Nottingham surveys) had said they had shopped with within their questionnaires (Appendix Z). Therefore, the type of sample for this this case study was it was determined as both a purposive sample as it was not randomly selected and convenience sample as they were situated near to the university and the research was undertaken without time or expense being wasted.

3.17.8 Communication with case studies

A senior marketing executive from one of the sub brands within the company emailed the university.

> '[W]e have a women's clothing brand called ----- which is marketed at the 50-65 year old market. The range is designed and cut specifically to fit a 50+ body shape as we understand our customers find it hard to buy well-fitting clothing on the high street. We are currently working on a marketing campaign to promote the fit of this range to

current and prospective customers and would like to use body scanner technology as part of a road show style event (Appendix AA:326).’

Meetings were scheduled both pre and post scanning project and the content of the meetings varied over the period of seven months. All but one meeting was timetabled at the university, with that one meeting being held at the company’s head office.

‘To explain a bit more about the activity I’m working on, we are hoping to set up a body scanner booth at a public exhibition/ event to use as a PR stunt as well as a consumer recruitment tool. Visitors to the stand would be able to have their body scanned and then we’d help them input the data into our virtual fitting room which is run in partnership with a company called Metail, this records the customer’s height, bust, waist and hips measurements and recommends the right size to order in each individual product. Our aim is for customers to have confidence that the ----- range is cut to fit their correct proportions and buy the right size first time.

We are currently considering Women’s Weekly Live as a potential venue as we sponsored this event last year and the demographic match perfectly with our target audience, this event takes place over 3 days at Event City, Manchester in September although we are also exploring alternative events to ensure we get maximum exposure with the right audience.

It would be great to discuss in more detail and get a rough understanding of the costs involved.’ (Appendix AA:326)

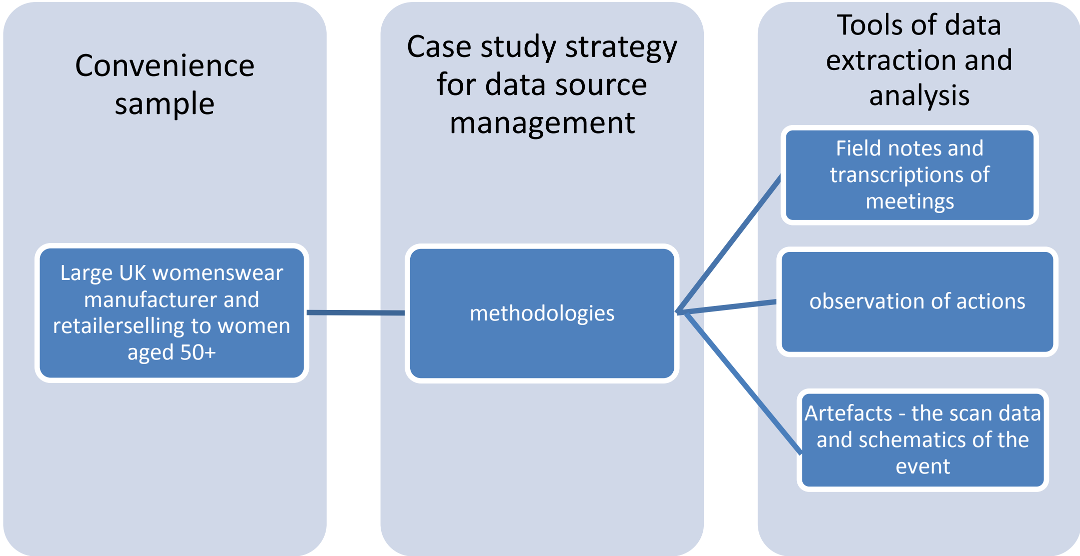


Figure 3-23 Framework for the case study

3.17.9 Methods of data collection pre-scanning project

The case study involved the collection of primary data in the form of minutes of meetings, emails and schematics of the scanning project as well as field notes detailing observations of the interactions between the company and the university (*Figure 3-23*). The university scanning team worked alongside the company, building a rapport with them, which meant observations, were recorded whilst participating in the scanning project. Creswell's (2009) study of mixed methods and more specifically observation techniques for qualitative data collection states an advantage of this role of participant/researcher meant that that data can be gathered through first-hand experience as events occurred. Plowright's (2011:67) analysis of types of observational research states an 'participant-as-observer,' allows for more interaction with those being researched in a naturalistic setting, which resulting in an honest response as the participants are not aware they are being observed. Observation followed a structured format in that the focus of observation was predetermined – and they were the ways in which the company wanted to use the 3D bodyscanner and its outputs – for that reason, observation was documented during meetings focused on the 3D bodyscanning project and at no other time.

3.17.10 Ethical considerations

Individuals from the company knew the university undertook research into mature females using bodyscanning technology but were not aware that they were being observed and documented for this very study. Creswell (2009) cautions that using this approach can mean that private/sensitive information of individuals could be recorded without their consent. This study was guided by MMU's ethical framework and consequently details of participants names, or contact details were anonymised, and, data not pertinent to this studies Objective [4] was not documented in the field notes and was removed from email correspondence to protect individual's privacy as well as sensitive company data.

Field notes recorded each meeting and after each day of the three day scanning project. Information of the meetings would be cascaded via email or discussed on the day. Name and job role was noted against each participant within the meetings. The rationale for providing job role was that it afforded context to an individual's viewpoint, which was necessary when this data was being analysed for emerging themes. Following each meeting, these notes were word processed and distributed to everyone present at the meeting. This provided an opportunity for individuals to validate the minutes as well as note down points for further discussion. This insured the minutes were as objective as possible.

3.17.11 Data collection at the company's scanning event (Activity 23)

The scanning project took 3 days and this research was actively involved (*Figure 3-1, Table 3-2*: Activity 23, 24 and 25). The company was responsible for participant recruitment and did this via mailshot using their existing customer base. Participants were also recruited during the event itself. Both approaches to sampling meant the final sample scanned at the event comprised of both a convenience and random samples.

Observations (in the form of field notes which were incorporated into the transcriptions in Appendix AA) of the company's actions and remarks when gathering and discussing the collected data was recorded in two ways – short notes at the time significant things occurred and more extended notes at the end of each day. It was determined that observation took a naturalistic approach in that the observations occurred in the company's natural setting (Plowright, 2012). Therefore an open coding approach – one which has less structured coding (Plowright, 2012), was taken to facilitate a level of semiotic analysis as the data was both semantic and visual.

3.17.12 Analysis of the case study data – qualitative data

All data - field notes, minutes, company correspondence and company artefacts developed with the university took the form of qualitative data (see Appendix AA). Having a mix of data formats – company artefacts, emails and so forth - are considered more reliable as it is not purely based on the interpretative field notes taken by the researcher (Silverman, 2006). It is also seen as providing triangulation as each data format can be compared to another thereby giving more confidence to emerging patterns or themes (Silverman, 2006).

This research took a structured approach to the data by initially reducing the data down into individual themes using tabulation, numbering paragraphs and then manual coding as main themes arose. Data reduction and analysis could have been undertaken using computer software such as Nvivo, however after further investigation into this type of software it was apparent that the data needs to be manually pre-sorted into files, meaning the analysis commences before any software is used. Manual data filtering and reduction gave this research immersion in the data, in much the same vein as it had immersed itself in the data collection process, and because if this immersion of key words, phrases, activities and themes became evident.

This portion of the study also contributed to Objective [4] which enabled the study to infer what industry's practices would be when faced with directly utilising the scan data. It also facilitated insights into whether the retailers made special provisions in the extraction of the required measurement for this particular demographic. Finally the completion of the case study involved analysis of the scan data to provide the company with a report and a radio interview which was utilised together within their advertising strategy and product development process.

4 Findings and Discussion – Part One

4.1 Introduction: the structure of the findings and discussion chapters

The Findings and Discussion portion of this research is broken into two chapters within this thesis as the research spanned six years, and although the research was undertaken on a part-time basis, the work is nevertheless lengthy. So to aid understanding and navigation of the work this portion of the research is separated into two chapters.

The is the Findings and Discussion – Part One presents and discusses the findings of Objectives [1], [2], [3] and [5]. This portion of the research covers application and validation of 3D bodyscanning technology by a clothing practitioner using participant engagement with the technology for pattern/garment development. The Findings and Discussion – Part Two presents and discusses the findings of Objective [4]. This portion of the work covers the application and validation of 3D bodyscanning technology for an industry partner to establish how they used the technology within their business model.

Objective [1] of this research facilitated understanding of the knowledge gaps in the existing knowledge base of automatic anthropometric landmarking through comparative analysis of body measurement (landmarking) and body measurement technologies. It also facilitated the commencement of experiential learning of the technology which ran from Objective [1] to Objective [3].

Objective [2] of this research assembled and identified relationships between manual and automatic methods of measurement using a survey approach to gather secondary data of previous surveys.

Objective [3] of this research evaluated the effectiveness of non-contact landmarking against the mature woman's body surface dimensions and body shape using comparative analysis of a younger female sample.

Objective [5] of this research developed a process and accompanying tools using the theoretical framework which integrates pattern construction with participant confirmed landmark definitions and measurement protocols to realise improved garment fit.

This chapter will, therefore, present and discuss the findings of this research in a chronological order starting with Objective [1]. There will be a brief discussion of how the collected data was analysed followed by the findings and then discussion. The Research Process Map (*Figure 3-1*) and accompanying Activities/Steps table (*Table 3-2*) as well as the Appendices will be cross referenced where needed. Each Activity has a number and this number will also be referenced to aid navigation of the Research Process Map. Details of how the methods were undertaken are already documented in the Methodology Chapter and these will be also crossed reference where required.

4.2 Utilisation and comprehension of 3D bodyscanning technology Objective [1]

4.2.1 <u>The findings of the 3D Bodyscanning Hardware and Software Overview Table (Activity 9)</u>

The first survey for Objective [1] was that of the 3D Hardware and Software Overview (*Figure 3-1, Table 3-2*: Activity 9) which can be found in its entirety in Appendix H. The search for information on 3D bodyscanning hardware and software consisted of analysing the written content of both academic journals and 3D bodyscanning branding and marketing literature for information on 3D bodyscanning hardware and software. Material concerning scanner brands was mainly sourced via the internet and the academic articles were available at Manchester Metropolitan University library. Analysis of the content involved splitting the relevant information into data entities under the titles as shown in *Table 4-1* directly below. Daanen and van de Water's (1998) paper which reviewed the then current 3D bodyscanning technologies provided initial ideas for the titles of the 3D Hardware and Software Overview table. As data for the table was gathered, reduced and compared it became clear that some 3D scanner brands had various limitations (which are discussed in detail below) and so it was decided that a limitations title should be added as well as titles to gather contact details and title for references.

Scanner Hardware and Software Overview

Proprietary Scanner	Technology	Software	Limitations	Size and purpose of scanner	Hardware configuration	Used in which surveys	Contact	Ref

Table 4-1 The titles used in the Scanner Hardware and Software overview

It was difficult at times to find comparable information within the data as information concerning different software specifications varied. This is noteworthy as this information was mainly sourced from scanner branding and marketing material that is developed to sell the product. As a result there are cells within the Scanner Hardware and Software Overview table, which have very little information in them when compared to other scanner, brands (please see Appendix H for the full table).

Scanner Hardware and Software Overview

Proprietary Scanner	Technology	Software	Limitations	Size and purpose of scanner	Hardware configuration	Used in which surveys	Contact	Ref
3D Digital Corporation Has models from Optix 400 H to 400 S. The higher the letter the better accuracy and resolution (3ddigitalcorp.com, 2009).	Laser from Optix 400 H to 400 S	Escan software produced by 3D Digital Corporation (3ddigitalcorp.com, 2009) Merges & aligns scans together. Allows 3D viewing. Appearance and colour can be adjusted. Scales and takes basic measurements. Allows point cloud and mesh formats to be exported (3ddigitalcorp.com, 2009).	Takes only basic measurements, the larger the scan the lower the accuracy or resolution (3ddigitalcorp.com, 2009).	Portable (3ddigitalcorp.com, 2009)	Uses the principles of laser triangulation. By making a triangle between the scanner lens, laser, and object being scanned 3D data is obtained (3ddigitalcorp.com, 2009). Speed of scan not discussed. Data is processed with the software SLIM 3D by 3D-Shape (3ddigitalcorp.com, 2009).	Used by podiatrists, dentists, forensics, automotive industry and museums artefacts. Company customises its scanners (3ddigitalcorp.com, 2009). NOT USED FOR ANTHROPOMETRIC SURVEYS AS YET.	http://www.3ddigitalcorp.com/3d-laser-scanner.shtml sara@3ddigitalcorp.com	**Contact:** (Showing All)
ABW	White light ABW 3D LCD-320 and two CCD-cameras (abw-3d.de, 2009)	**ABW 3D software** ABW-3D is a dynamic link library (DLL). It is written in object oriented manner in C++. You may integrate it in an existing visual system. It is hardware-independent and makes no graphical output. Your system keeps complete control of the graphical user interface. ABW-3D just gets the images from your system and returns the results (abw-3d.de, 2009).	Only scans small sections, can lose areas because of the method of scanning (abw-3d.de, 2009).	Small scanner not whole body.	One projector and two cameras (abw-3d.de, 2009).	Face scanner NOT USED FOR ANTHROPOMETRIC SURVEYS AS YET.	ABW GmbH Siemensstraße 3 D-72636 Frickenhausen info@abw-3d.de	abw-3d.de, (2009)

Table 4-2 Example of the data collated within the Scanner Hardware and Software Table (Activity 9)

The Scanner Hardware and Software Overview table also showed that there are many scanners on the market but their limitations were not all are suitable for clothing purposes in that their hardware configuration maybe too small, their resolution is not high enough, their light source is not eye-safe, the scanning area is not private or it has not been designed specifically as an anthropometric tool (see Appendix H).

The research also found that scanner branding and marketing material used many technical terms within its information which would be difficult to understand without a computer science background. For example terms such as 'user graphical interface', 'mesh formats', 'laser triangulation', 'polygonal model' and 'data interpolation' were used and no definition was provided. This research found it did understand these terms within the scanner specification but only after it had sourced literature concerning image capture, processing and storage as discussion in section 2.7 of the literature review chapter. This implies that to fully understand the content of scanner branding and marketing material thorough and extensive research is necessary for those not familiar with computing terminology, such as a clothing practitioner. This kind of research would presently be necessary for a clothing practitioner to understand and apply the technology once purchased. Given the time pressures of the clothing industry (Wren and Gill, 2010) this depth of research seems highly unlikely, and it therefore could be concluded that they would be reliant on what the 3D bodyscanner company representatives tells them to aid them in their understanding. It can be concluded therefore that these sources of information would help them make their decision of whether to adopt the technology or not. This lack of understanding of the technology is perhaps one of the reasons why adoption has been so slow.

The Overview of 3D Bodyscanning Hardware and Software table also revealed that of all the scanners listed only the Telmat (Appendix H: row 23) and Sizestream scanners (*Figure 4-3*) state that their measurement extraction files complied with ISO-8559 and ISO-7250 standards for automatic landmark detection. It is therefore noteworthy that important information such as the standards the landmarking and measurement extraction is based on is omitted from the most scanner brands marketing material, even the very latest marketing material produced by market leading scanner brands as shown in *Figure 4-1* and *Figure 4-2*.

A review of the content of bodyscanning branding and marketing literature revealed that 3D bodyscanning companies advertise their products as 100% accurate. This is also a view held by some researchers who state replicability of measurement is the factor which determines its accuracy (Bretschneider et al, 2009 ; Fan *et al,* 2004 and Yu et al, 2003). This is correct in that the technology, when required, will produce the same measurement if the parameters for that measurement are not altered. However more current research (Gill *et al,* 2014b and Bragança *et al*, 2015) states that bodyscanning technology cannot be 100% accurate given the variables involved (age of the participant, their size and posture, the configuration of the hardware and the definitions of the landmarks used) in the 3D bodyscanning process, and their potential to effect the process that accuracy cannot be taken as granted without a scan validation process.

Three dimensional bodyscanning companies (see*, Figure 4-1, Figure 4-2* and *Figure 4-3*) term their technology as state of the art and ideal to use as an anthropometric survey tool. Phrases such as 'high precision', 'best in class accuracy', 'reliable body measurements', 'reduced production risk', 'most advanced', 'consistently high and reproducible measurement accuracy' and 'market leading features were common phrased found within the marketing material (see examples below in *Figure 4-1, Figure 4-2* and *Figure 4-3*). These phrases have been carefully worded to incite confidence in the technology for the user, as any marketing material would. However, King's (2015) report (discussed in section 2.7.3) concerning 3D bodyscanning and its application states confirms that bodyscanning companies research into improving the speed of capture, the portability of 3D bodyscanning equipment and the cost and the accessibility of the technology is ongoing, indicating that the companies are aware that the technology has limitations which need improvement. It may also be that these companies are under pressure to continue developing the technology due to rival competition and/or other commercial pressures. For example, TC², a market leader in 3D bodyscanning technology listed in Appendix H, has worked to advance its product by using new light-source technologies which they claimed improved scan capture times, portability and cost of each system.

The advancements listed by two 3D bodyscanning companies in *Figure 4-1* and *Figure 4-2* below are used to market and sell the technologies to both new and existing clients, indicating that the companies believe the advancements are necessary for their sales strategy. This could indicate that these companies are responding to new and existing clients' needs for the acquisition and application of 3D bodyscanning technology. Conversely, the continued development of the technology's software could also indicate that the previous 3D bodyscanner models were limited by the available technology, at that earlier time of development, and this could have resulted in inadequate image capture and measurement extraction. If this latter reason is the case, then it can be inferred that the earlier software may have impacted on the results of previous anthropometric surveys.

This research used two TC² scanners, one of which did not have the three improvements (faster image capture, portability and reduced cost) and one of which did. The implicit understanding of academics using 3D bodyscanning technology at Manchester Metropolitan University was that the newer model of scanner with these three improvements was an improvement in terms of time and accuracy of scan, although as a place of research, judgment was reserved until the newer technology was put into practice, a view espoused by a 3D bodyscanning company expert (2.7.1).

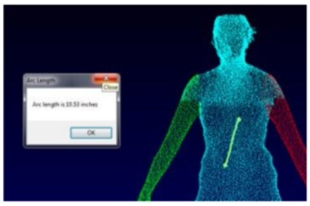
HOME | COMPANY | PRODUCTS | MARKETS | REFERENCES | CONTACT US +

Finance as Low as...
$594 / month

TC2-19B: THE NEW ERA OF 3D BODY SCANNING IS HERE

The TC2-19 3D body scanner is the best in class from the world's first and largest 3D body scanner manufacturer serving the fashion, medical, and fitness industries. The most advanced way to answer all body scan and body measurement needs.

STATE OF THE ART FEATURES



· Scan in 1 second

· 4D mode

· 1000's of different Measurements

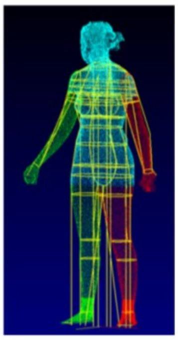
· Best-in-class Accuracy

- Point to Point Measurement

- Full 3D Color scan mode

- Full 3D Color scan mode

USES OF 3D SCANNING TECHNOLOGY INCLUDE



· Virtual fashion

· Made to measure clothing

· Sizing surveys

· Body shape analysis

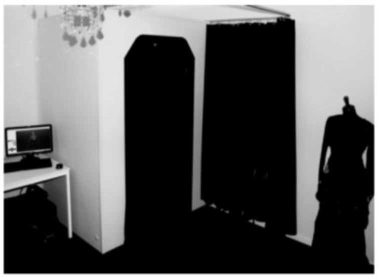
· Health/medical and fitness

· 3D printing

· 3D product development

SPECIFICATIONS

Features:



· Changing area (with curtain)

· Full privacy scanning booth

· Recorded audio instructions
played through speakers in booth)

· 2 height-adjustable handholds

· Compact scanner footprint

· No moving parts

· Scan in any color of close fitting garment

· 4D mode to visualize 3D movement

· Selectable hair-masking mode
(Scanning software can automatically mask subject's hair and part of the head so measurement extraction is unaffected by hairstyles.)

· Superior crotch point detection

· Self-scan mode (no operator needed), with an optional touch screen inside the scanner booth. With the new fully customizable user interface in auto mode, the customer can operate the

scanner.

· MEP configurator to define desired set of extracted measurements

· Batch process scans

· Avatar and virtual fashion interface (avatar creation)

· PC table included

· Scanner software license included

· If packaged with ImageTwin offers avatar creation, poses, animation, size matching, virtual fitting, personalization, and styling advice

· Measurements can be exported through txt to excel and word.

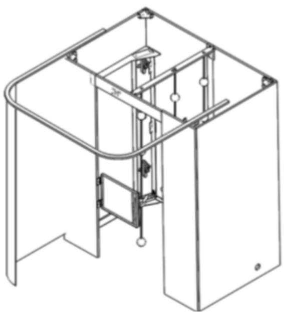


Figure 4-1 TC² 3D body scanning latest marketing material

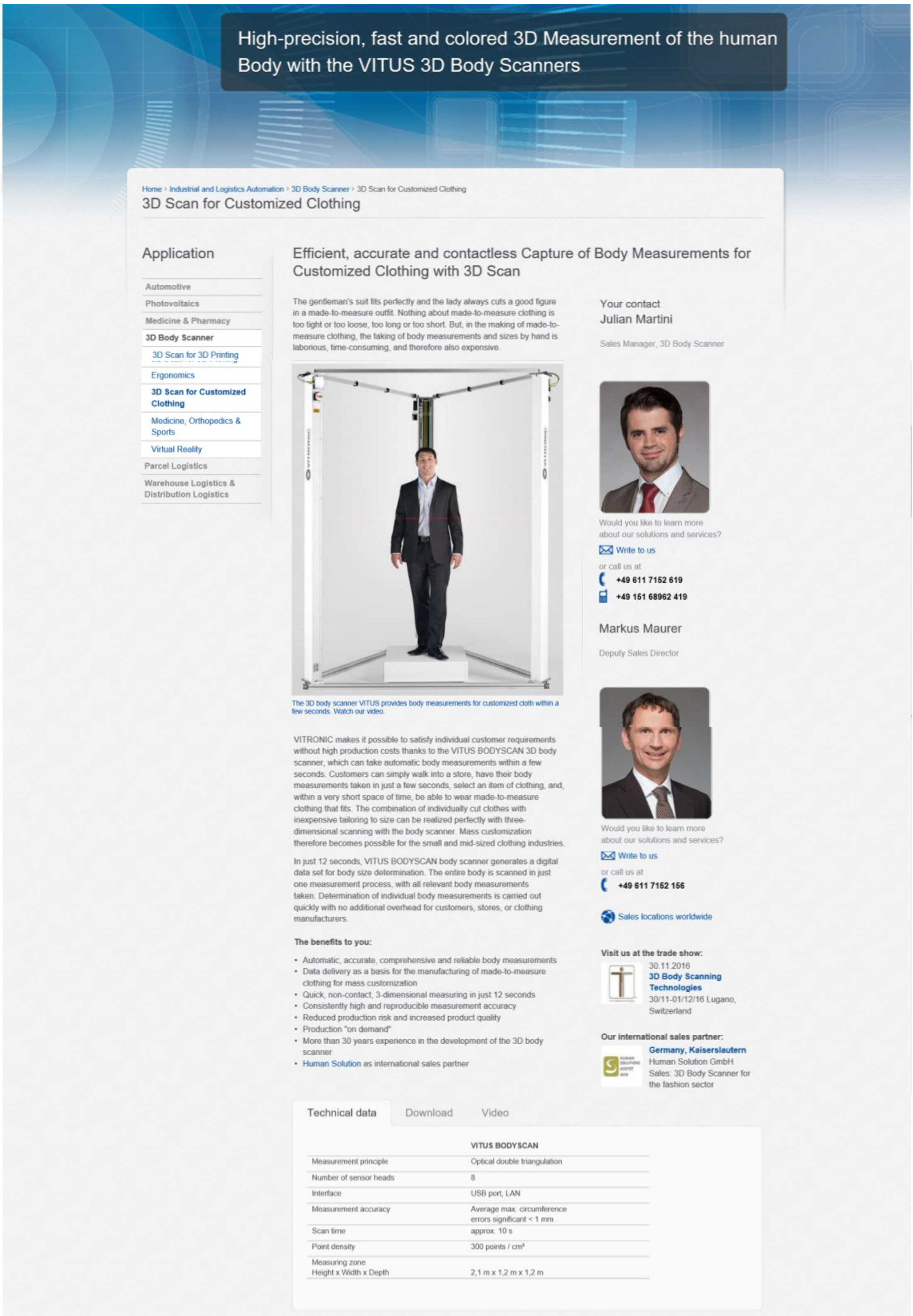


Figure 4-2 Vitus 3D body scanning system latest marketing material

SIZE STREAM™

SS20 3D Body Scanner

Market Leading Features:

- Scan in 4 seconds
- Smallest footprint: 1.4 x 1.1 meters
- Internal touch screen – self scanning
- Hidden CPU

Applications Include:

- Custom Clothing
- Size Prediction
- 3D Printing
- Measurement Tracking
- Size Surveys
- Fitness
- Medical

Addressing 3D Body Scan and Body Measurement needs from Research to Retail with High Quality and Low Cost Body Scanners with Automatic body scan Measurements…

Available 2Q 2017

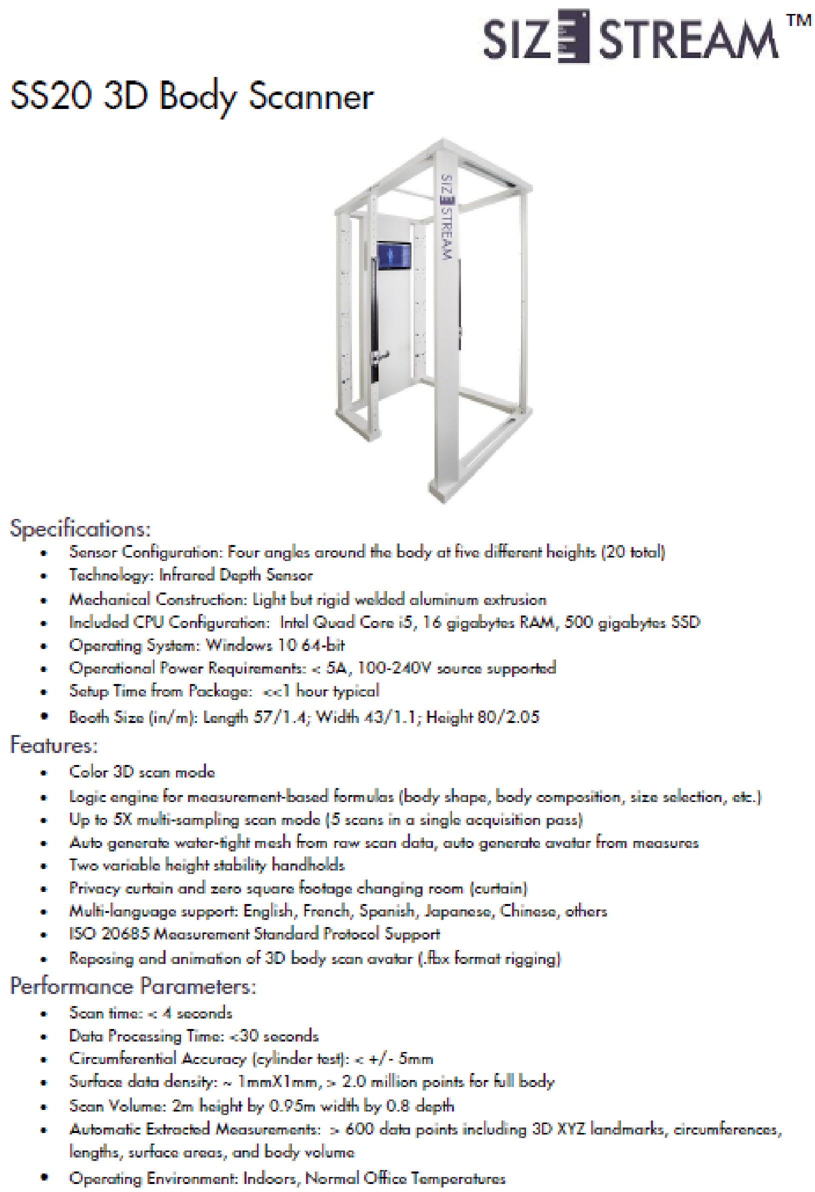


Figure 4-3 Size Stream latest 3D bodyscanning marketing material

When collating and scrutinising different 3D bodyscanning brands and their marketing literature, and more specifically the software they used for the table (Appendix H), it also became evident that even though some systems offered a form of user interface with the software, this was limited as the companies software is proprietary and as such not open to direct graphic manipulation. For example, some systems allowed measurement files (TC² uses MEPs) to be written within a database. The terminology and descriptions of these algorithmic processes and their manipulation would be unfamiliar to clothing practitioners.

Many of the market-leading branded scanners such as TC² and Vitus are sold with a database interface facility yet this research found that detailed information on how to use it is sparse and could not be found within any reference books or online resources. This finding was published in Gill et al's (2014b) paper of which this research contributed, please see Appendix AI for more context. However, since the publication of Gill et al's (2014b) paper this research progressed further and found that this disparity became more distinct when it examined scanner marketing literature and compared and contrasted it to that of the literature produced by clothing academics. Interestingly, neither source defined the bodyscanning software and hardware terminology thereby implying, consciously or unconsciously, that the consumer of this literature must already possess a sufficient understanding for a glossary or definition of terms to be unnecessary. Moreover this research found that the terminology used in scanner marketing material was technical in nature and gave details on files types, hardware and software interfaces, and the constitution of the virtual surface see Appendix H for details and *Figure 4-1*, *Figure 4-2* and *Figure 4-3* as examples. Academic literature, such as the work by Han et al, 2009; Ashdown & Na, 2008, Pargas et al 1997; Han & Nam, 2011, focussed on clothing development and all discussed the application of 3D bodyscanning within the context of clothing development. Their work used similar technical terms to that of bodyscanner marketing material but, ultimately, their work did not provide explicit definitions for the reader either. Terms found within academic literature concerned with 3D bodyscanning development such as 'polygonal mesh' (2.8.4); 'noise' (2.7.3); 'point cloud' (*Figure 2-18*); 'Procrustes rotation' (*Figure 2-17*) and 'Reeb graph' (*Figure 2-15*) are not terms used widely in an industrial clothing development environment and if definitions are not explicit in academic literature aimed at clothing practitioners it would prove challenging for those not familiar with computer science or who have never encountered 3D body scanning before to become engaged.

4.2.1 The findings of the landmarking methods survey (Activity 10)

The second survey for Objective [1] was the Survey of Landmarking Methods (*Figure 3-1, Table 3-2*: Activity 10) which can be viewed in its entirety in Appendix M. During the development of this thesis proposal the idea was that this PhD research may be able to develop its own non-contact landmarking method/computer file to use with the TC^2 bodyscanner supported by knowledge and skills of vector graphics and CAD gained from 18 years working in the clothing industry and 1 year as an academic in higher education. It was reasoned that as the TC^2 scanner was targeted at the clothing industry, however at this point this research had not started to use the scanner and so was not aware that the proprietary software interface is inaccessible to all but [22] company personnel. Therefore this avenue appear closed and alternative approaches to anatomical landmarking were considered but they had to work within the confines of a clothing practitioner's skill-set and the limitations of the TC^2 technology. Details of this are a part of Objective [3] and will be outlined later in this Finding and Discussion Chapter.

Nonetheless, this research wanted to find out how novel landmarking methods were developed as a means to understanding 3D bodyscanning technology further. Papers concerning novel semi and non-contact landmarking methods for the literature review indicated that work had been undertaken but many of the researchers developing these methods had skills sets outside of those possessed by a clothing practitioners (2.8.3). Their methods appeared difficult to replicate without a background in statistics or computer science. Therefore this research decided to create the Landmarking Methods table to compare, contrast and explore the information on more novel landmarking methods to better understand their ease of replication, their appropriateness for measuring women aged 55+ and how these methods differed from that of manual methods (of which this research was very familiar with having measured many women over the course of 18 years for clothing development). The table of landmarking methods was novel in that nothing exists of this nature in the current literature base.

The information not unlike the previous survey discussed above used tabulation and a series of titles to display data entities derived from academic research papers. The titles for the table can be seen in *Table 4-3* below. Ideas for the titles of this table came from Simmons and Istook's (2003) paper that reviewed different scanner brands non-contact methods of landmarking and measurement extraction.

Landmarking Methods Table									
Landmarking Method	**Method name & subject/researcher/software involvement**	**Used in which study**	Anatomical positioning	**Protocols for implementation**	**Used for Identifying which landmark**	**Skill set needed to implement**	**Landmarking methods relationships & combination**	**Landmarking method accuracy**	**Critique**

Table 4-3 The titles used for the Landmarking Methods table

These titles again enabled like-for-like information to be extracted from different academic papers for comparison. So for example, the tile 'protocols for implementation' enabled this research to extract information from each research paper on the exact process each novel method used. In this instance the function fitting method show in *Table 4-4* below requires specialist knowledge of 3D computer graphics manipulation and image recognition for its implementation and is therefore outside of the scope of a clothing practitioner and could not be implemented within the TC² software system without computer hacking skills. Many of the novel landmarking methods, found, required these skills which at present creates a barrier of comprehension to those without a computer science or statistics background.

Landmarking Methods Table									
Landmarking Method	**Method name & subject/researcher/software involvement**	**Used in which study**	Anatomical positioning	**Protocols for implementation**	**Used for Identifying which landmark**	**Skill set needed to implement**	**Landmarking methods relationships & combination**	**Landmarking method accuracy**	**Critique**
Automatic. A pre landmarked deformable template is placed over the region of interest.	Function fitting, requires little engagement with the scan subject. and much of the work is done after the scan is completed.	Suikerbuik et al, 2004	Natural standing position only.	Subject is scanned. The scans are then sorted into shape categories. The scans are divided up using bounding boxes into areas of interest. These areas have point subset configurations which denote a specific type of skin surface terrain in which the landmark is present. This template is not rigid due to a different similarity function which allows the template to deform within set tolerances determined by a Gaussian distribution function (Appendix J). The landmark is at the peak of the distribution and tolerances are set either side of that distribution arc The parameters of the distribution function are estimated by non-linear regression, so that the distribution function will resemble the region of interest." (suikerbuik et al, 2004) The lowest value signifies the best fit.	Sellion (Appendix D Glossary of terms) and medial malleolus (Appendix D Glossary of terms) for this study. It is possible to use for other landmarks but the more visible the landmark the more accurate the method is.	Anthropometric training and an in-depth understanding of 3D computer graphics and geometry.	**Strong relationship** with other automatic methods in that it does not need operator intervention. **Weaker relationship** with semi automatic methods as landmarks are predetermined on the template by a human operator.	Accuracy levels are if the subject moves or the scan image is not clean of enough noise. A large library of templates is needed to closely match each subject. Only tested on sellion and malleolus which have a visually apparent surface terrain.	Not tested on females over 55 years of age.Manipulation of the method requires skills in computer science and therefore is not suitable for a clothing practitioner who is not required to possess those skills.

Table 4-4 An example of an entry within the Landmarking Methods Table (Activity 10)

When building the Landmarking Methods table in Appendix M, it became evident that research on automatic landmarking methods came from a variety of research bases and disciplines, often not directly concerned or connected with the clothing industry at all (2.8.1). This included research developed by computer scientists and statisticians whose methods and conclusions requiring in-depth specialist knowledge which often involved the writing and manipulation of computer code or expertise to understand and undertake complex calculations as discussed in section 2.8.2 and shown in *Table 4-5*. These processes and the level of technical expertise would often be unavailable to clothing practitioners and, therefore, not widely utilised by the clothing industry as a whole.

Landmarking M	**Method name & su**	Used in w	Anatomic	Protocols for implemen	Used for l	Skill set n	Landmarking	Landmarking	Critique
Requires a 3D scanner. Automatic, match a surface of which all relevant information is known (a template) onto another surface (suikerbuik et al, 2004). Follows the principles of image or shape recognition. A template is developed using similar shape body parts which also share a similar point cloud configuration. There is a great deal of preliminary work to be done for this method as many different shaped templates need to be developed.	Template matching much of the work is done after the subject has been scanned.	Suikerbuik et al, 2004	Natural standing position	There is preparatory work to be done before the templates can be applied. Scans are segmented into areas of interest (landmarks) in readiness for the template to be made. Templates are developed from these scans. These scans will have similar point patterns (similar shape) and the landmarks will appear in a similar region. The template will be developed from a small subset of points containing the landmark. This information is held within a bounding box. Location of this bounding box on the body is stored as a written directive by the operator, so the software knows the origin of the point subset. Using euclidian distance, an algorithm (similarity function) is developed to determine the best template fit around the segmented body part between the template and the scan points. Once the templates and similarity function were developed the method was automated.	Sellion and medial malleolus for this study. It is possible to use for other landmarks but the more visible the landmark the more accurate the method is. For example accuracy was greater on the malleolus which is the ankle bone seen from the outside side view of the foot. This bone	Knowledge of anatomy theory. Training in writing computer software.	**Strong relationship** with any method that uses vectorised skin surface analysis.	Accuracy levels depend on the amounts of templates available within the software.	Individual scans can produce variable amounts of points within the point cloud so it is difficult to match up subjects to templates if there is a variation in the point cloud configuration and density.
This method constructs computer functions via neural networks to characterise and search features individually over the body surface. The function requires descriptions of local feature attributes along the skin surface terrain so landmarks can be located within the local feature attributes.	Automatic Feature discriminent functions. Subject is scanned and this function works during the vectorisation (Appendix D)of the captured bitmap image. There is no interaction between the subject and the method.	Discussed in Dekker *et al,(* 1999)	Not stated although all images used within the publication are shown in the standing position with held arms away from the sides of the body.	Subject is scanned and the digitised skin surface is cleaned and smoothed. Body model is skinned to provide a base using either B-spine or polygonal primatives. Functions are written by human operators into the software to characterise and search for body features individually. The functions are developed using shape descriptors which are viewed by the software in the context of whole body attributes. These functions can detect relevant body features and primary landmarks such as branching points in the armpits and crotch. The function then goes on to detect more subtle landmarks using the branching points as a context for subsequent detectors.	whole body	Training in anthropometrics and 3D computer imaging	**Weak relationship** with manual and semi automatic methods as all use visual analysis of the skin surface terrain to assess its characteristics for clues to landmark location. **Strong relationship** with other automatic methods as it uses 3D geometrics to evaluate skin surface terrain.	Only as good as the landmark definitions used within the descriptors.	There is some critique of the method within this paper in the form of comparative analysis between this and another similar automatic method (Global deformable templates). However the paper is largely descriptive and its sample set does not contain individuals within the very obese BMI category and is therefore not truly representative of the whole UK population.
Automatic method. The method is based on learning landmark attributes and their spatial relationships between other landmarks from a set of human scans.	Statistical analysis and statistical learning algorithms. No integration with scan subject. No integration with the scanner operator.	Azouz *et al ,* (2006)	They used CASEAR data which did include subjects in sitting positions. However their research only used the data from the subjects in a standing position with held arms away from the sides of the body.	Scan data is needed. An algorithm is formulated by looking a scans of male subjects who display different body sizes and shapes. The scans are prelandmarked and values between these areas are extracted and statistically analysed to form a landmark graphic of average distance and most likely neighbouring landmarks using a statistical imaging tool called a pairwise Markov random field.	Whole body. Paper shows images of a subject whose head, arms legs and torso have been landmarked.	Knowledge of statistics and 3D graphics is needed to develop or amend the method. As this study used secondary scan data a knowledge of landmarking was not needed. A clothing practitioners would not have the skill set to implement this method.	**Strong relationship** with Feature discriminate functions as both methods scan the vectorised skin surface to look for surface characteristics of or around the landmarks. **Weak relationship** as skin surface terrain is visually evaluated for areas of interest.	Shown to be more accurate and more objective than semi automatic methods. However the method was only undertaken on male subjects so it would need to be tested on female subjects of different ages and body sizes/shapes.	Used males subject only so it is doubtful if it would be effective for females over 55+.

Table 4-5 Examples of protocols for implementation which require computer science and advanced statistics backgrounds

That is not to say that the development of 3D bodyscanning has had no input from researchers with a clothing background. Robinette & Daanen, 2006 and Burnsides *et al,* 2003 have explored landmarking practice using semi-automatic methods, which palpate and demarcate particular landmarks on the skin surface prior to scanning individuals (*Table 4-6*). This demonstrated a more practical approach to landmarking which resonated with traditional manual practice (Honey & Olds, 2005) grown out of historical craft-based methods of garment development and generation. A strategy such as this is more familiar to and supported by the existing knowledge and skill sets of current industry clothing practitioners. Such a fundamental approach, using skills already available to industry clothing practitioners, had the added advantage of allowing participant engagement with the process. This is particularly advantageous for individuals whose body size and shape fall outside of standard parameters, and would be appropriate for the 55+ female demographic.

Landmarking M	Method name & su	Used in w	Anatomic	Protocols for implemen	Used for l	Skill set ne	Landmarking	Landmarking	Critique
Initial manual human palpation to locate and physically mark subject's landmarks with stick on markers. Location of the marked landmark is achieved in two ways. First the marked landmark is located via it colour and vector shape formation so the software is looking at both mathematical points in 3D space and colour voxel formations (the software wants to find the clear white centre of the marker). Second the marked landmark is cross checked via a heuristic rule which is a written directive algorithm containing the name and a very comprehensive definition of the landmark (. Finally the landmark location and name are verified and validated using another software	Semi-automatic measurement method. Part of the measurement method is accomplished with the subject being present. Part of the work is accomplished by researcher engaging with the software and part of the work is done automatically. The approach was to manually mimic an automatic point detection process using human operators and once the accuracies are with an acceptable tolerance percentage the process is automated (Burnsides et al, 2003).	Somewhat similar to Geisen et al's (1995) previous semi automatic methods. Was developed for the CAESAR survey.	Standing position with held arms away from the sides of the body.	The paper does not specify subject numbers or subject selection criteria. A subject is manually palpated and landmarks are located. The paper states that to landmark an entire body 72 landmarks need to be located and marked (Burnsides et al, 2003). The markers shape and dimensions vary depending on the visibility of the landmark to the scanners cameras. So for areas such as the crotch point, which can be difficult to locate (Zhong & Xu, 2006, Nu & Zhang, 2009) "a white rubber object approximately 10mm square at the base, 7mm square at the top and 6mm high was chosen for these landmarks" (Burnsides et al, 2003, 394). 12 landmarks were labelled up with these style of markers (Burnsides et al, 2003). All other landmarks which are clearly visible to the scanners cameras were labelled with 12.5mm white dots (Burnsides et al, 2003). The landmark extraction process was broken into 3 categories: 1 detection of candidate points, 2 identification of each candidate	Whole body. Paper shows images of a subject whose head, arms and torso have been landmarked.	Training in manual palpation and marking of anatomical landmarks. If the software is not already set up a detailed knowledge of vectors, statistics and computer software writing is needed. If software is already set up all the operator needs to assess is if all markers are present in the	**Strong relationship** to manual methods whereby the operator has to visually assess and then palpate the skin surface to locate the landmark. **Weak relationship** to template matching as this initially involves operator engagement in the development of placing the landmarks within the templates. **Weak relationship** to feature discriminate functions rely on operator derived descriptors of the skin surface some thing which would be found in a manual anthropometric survey manual. No relationship to statistical analysis.	Reported as being good for all landmarks (Robinette & Harrison, 2002, Robinette *et al*, 2002; Burnsides *et al*, 2003) as there was no reliable automatic landmarking method developed at the time for the CAESAR survey. The data from this survey has been used in other studies due to its reliability	Survey only scanned subjects up to age 65 (Robinette et al, 2002) so it cannot be assumed that this method is suitable for the body morphology of female subjects over 65. This method is reliant on operator diligence in the palpation, marking and scan assessment phase. Many papers, including Burnsides et al (2003) have stressed human error

Table 4-6 Extract take from the Landmarking Methods table: The only landmarking method accessible to clothing practitioners

However, progress in the field of anthropometrics appeared to be following a non-contact approach to anatomical landmarking as evidenced by the continuing usage of 3D bodyscanning technology for survey purposes (please refer to Appendix A for full context) and the fact that only one (as seen in *Table 4-6*) out of the ten identified landmarking methods within the Landmarking Methods table (Appendix M) which is developed for use with 3D bodyscanning technology developed an approach (semi-automatic landmarking) which is accessible to a clothing practitioner.

Given the significant usage of 3D scanning technology for anthropometric purposes, as in Size UK and Size US (see Appendix A), anatomical landmarking is clearly an area suitable for current research and one which should involve the expertise of anthropometric and clothing practitioners, particularly if it is being used to landmark mixed demographics for clothing development.

However, one of the most salient findings of this research that had not been highlighted in any study to date was that research into non-contact landmarking (2.8.1) was principally undertaken by experts from the fields of statistics and computer science without direct input from anthropometric experts or other associated industry practitioners who have a practical knowledge of anatomical landmark location. For example, research undertaken by Suikerbuik *et al*, (2004); Zhong & Xu, (2006) – all used scans which were captured from other surveys that may or may not have been through a process of scan evaluation and validation. They based the accuracy of their developments on scans that had been pre-landmarked by a third party thereby assuming that they need not explore and understand the practice of anatomical landmarking itself.

This imbalance in expertise compounds accuracy issues in automatic landmarking as direct expertise from each field is necessary to tailor automatic landmarking methods for different applications, genders and demographics, as has been the case when traditional anthropometric methods have been used in the past (2.5.1). Consequently, the separation of expertise by discipline is a problem for all practitioners and research would benefit from closer inter/cross-disciplinary collaboration.

4.2.1 <u>Summary of the findings of the Scanner Hardware and Software Overview and the Landmarking Methods tables Objective [1] (Activities 9 and 10)</u>

In summary, this portion of the research found that the barriers to comprehension and adoption of 3D bodyscanning technology were threefold. Firstly, the research literature was generated by disparate disciplines. Secondly, that the proposed solutions and practices were outside of the skill set of current clothing practitioners. This was exacerbated by the fact that those academics typically generating the research relating to the development of 3D bodyscanning software were not connected to clothing development. Thirdly, the barrier to comprehension and adoption of 3D bodyscanning technology was the finding that although computing terms were used in both marketing and clothing development literature, neither source explicitly defined what these terms were or how they were applied within the software. These findings indicate a requirement to make 3D bodyscanning more accessible to both new and existing clothing practitioners which would aid it adoption and application within the clothing product development process. New technologies such as 3D bodyscanning technologies require widespread teaching/training within higher education institutions to enable understanding of their systems and how to apply them within the clothing product development process. This suggests the need for new approaches to teaching the technical side of clothing product development to equip new and existing clothing practitioners with new skill sets to manipulate 3D computer graphics using image recognition and statistical methods. This research found that knowledge of 3D bodyscanning at present remains within a small circle of academics and bodyscanning companies with the latter offering little information on the landmarking definition algorithms. Three dimensional bodyscanning companies are protective of their software algorithms as this is part of their competitive advantage (2.7.4). Whilst some of the definitions for non-contact landmarking methods had been published - such as the work of Simmons and Istook (2003) –commercial reasons dictated that no supplier of 3D bodyscanning systems explicitly explicated how the software algorithmically generated the anatomical landmarks. The findings of this research indicated that confidentiality concerning the algorithms used in commercial systems rendered the data extracted from scanning opaque as it could not be benchmarked against existing traditional methods or identified as objectively accurate by users of bodyscanning technology. Therefore, commercial confidentiality hampered the adoption of use of 3D bodyscanning technology for clothing practitioners.

4.1 The relationships between manual and automatic anthropometric measurement and the assemblage of the conceptual model Objective [2]

4.1.1 <u>The findings of the Anthropometric Survey table (Activity 11)</u>

Objective [2] began a survey of anthropometric surveys (*Figure 3-1, Table 3-2*: Activity 11) which focussed on gathering and evaluating information of international anthropometric events to populate the Anthropometric survey table which can be found in its entirety within Appendix A. The information used to populate this table came from both academic and governmental sources which have used 3D bodyscanning technology to gather information regarding population's body size and shape. The methods used in the 3D Bodyscanning Software and Hardware Overview table were used for the Anthropometric Methods survey in that a table was generated which separated the information under particular titles for comparison as shown in *Table 4-7* below. The suggestions for titles came from reviewing the previous anthropometric studies/reports of O'Brien and Shelton (1941), Kemsley (1957), Lohman (1988), Beazley (1998) and NHANES (2007). All of these are manual anthropometric studies and their content covers the titles outlined in *Table 4-7* below.

Country	Year	Demographic and socio-demographic infomation gathered	System used	Body undertaking survey	Amount measured or scanned	Number of measure-ments taken & if landmark	Contact	Survey Published	Purpose of survey	Ref

Table 4-7 The titles of the Anthropometric Survey table

In total 26 anthropometric surveys were found and documented in the Anthropometric Survey table (see Appendix A). The table titles (as shown in *Table 4-7*) recorded the country in which the survey had been undertaken, the year of the survey, the demographics that provided the body measurement data, the type of measurement system which was used (this could be manual or non-contact and if non-contact were used then the scanner brand was names), the persons/organisation which undertook the survey, the sample gender and size, the number and name of measurements taken, the person to contact to discuss the survey, if the survey had produced a published report, the purpose of the survey and references to show where all this information had come from.

The Anthropometric Survey table established that, 23 of 26 surveys used non-contact 3D bodyscanning technology as a survey tool. The Anthropometric Survey table also highlighted that non-contact methods were being used globally for the collection of body dimensional data (see Appendix A for the full table). Areas covering America, the Baltics, Asia and Europe all used the technology which implies an acceptance that the technology was fit for purpose at that time. Interestingly countries such as Australia, India and Bulgaria used manual measurement techniques for their anthropometric surveys between the years of 2002-2008 demonstrating that manual anthropometric methods are not obsolete at this time.

The Anthropometric Survey table also illustrated that 3D bodyscanning had consistently been used in between 1997-2008. Again this continued usage for more than 10 years shows a trust by each of these organisations/countries in the precision of 3D body scanning technology and its fitness for purpose.

The Anthropometric Surveys table also found that 3D bodyscanning technology was being used for all ages and genders, seemingly without any adjustment to software or hardware configurations as no mention of such adjustments were found in the literature which documented each survey. This is concerning as without information on what international standard the landmarking process is based on (as discussed in section 4.1.1), and no record of adjustment for either the hardware or software for non-standard body morphologies (as has been established as necessary in section 2.5) it is difficult to determine how accurate the surveys were, and difficult to ascertain how successful 3D bodyscanning was before this thesis was undertaken. This infers that users of the technology for the purpose of anthropometric surveys feel no adjustment is needed to the technology and that it can be used for all genders and ages without adjustment.

The Anthropometric Survey table also illustrated that only 11 of the 26 anthropometric surveys found provided details of the measurement they took. Of the eleven, ten surveys were non-contact. Further investigation of the 10 non-contact surveys measurement details indicated that detailed landmarking information such as landmark definition and demarcation was non-existent which is markedly different from that of manual methods whereby each landmark is defined and its demarcation is explicitly described shown below in an extract of the NHANES (2007) report, *Figure 4-4* and *Figure 4-5*.

3.4.7 Arm Circumference

The anthropometry protocol calls for two circumference measures on participants aged 2 months and older: arm and abdominal, or waist, circumference. The arm circumference is measured on the right arm at the level of the upper arm mid-point mark. The examiner makes this mark on the posterior surface of the arm immediately after measuring the upper arm length. Thus, the procedures for making the mid-arm circumference mark are explained in Section 3.4.7, Upper Arm Length shown earlier. This section describes the procedures for measuring the arm circumference:

1. **Position the SP:** Ask the SP to turn so that you stand **facing** his or her right side. Have the participant stand upright with the weight evenly distributed on both feet, the shoulders relaxed, and the right arm hanging loosely at the sides. Flexing or tightening the arm muscles will yield an inaccurate measurement.

2. **Take the measurement:** Continue to stand **facing the right side** of the SP. Do not stand behind the SP for this measurement. Wrap the measuring tape around the arm at the level of the upper arm mid-point mark (Section 3.4.7). Position the tape **perpendicular** to the long axis of the upper arm. Pull the two ends of the overlapping tape together so that the zero end sits below the measurement value and the result lies on the lateral aspect of the arm (not the posterior surface). Check that the tape fits snug around the arm but does not compress the skin. Take the measurement to the nearest 0.1 cm.

3. **Record the result:** Call the result to the recorder, who will enter this number on the ISIS screen. Remove the tape measure. Using the cosmetic pencil, **write the arm circumference measurement** on the front right part of the gown shirt of all participants aged 8 years and older. This number is used to determine the appropriate cuff size for taking the SPs blood pressure in the Physician examination. Proceed to the next circumference measure.

3.4.8 Abdominal (Waist) Circumference

The second circumference measure consists of the abdominal or waist circumference. Exam staff will collect the waist circumference on participants aged 2 years and older. Follow the procedures below to obtain this measure:

1. **Position the SP:** Instruct the participant to gather his or her gown shirt above the waist, cross the arms, and place the hands on opposite shoulders. Demonstrate the desired position of the arms. It may help to tell SPs to think of giving themselves a hug. If necessary, lower the pants and underclothing to slightly below the waist. Again, always tell the SP what you are going to do before you do it.

3-15

Figure 4-4 Landmark definitions and measurement descriptions from NHANES (2007) anthropometric survey report Source: NHANES (2007)

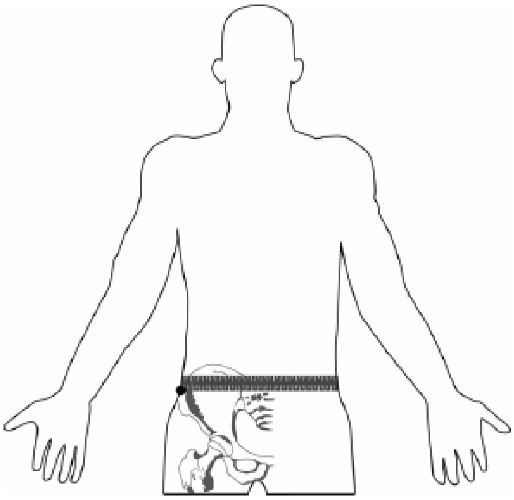
2. **Mark the measurement site:** Stand on the participant's right side. Palpate the hip area to locate the right ilium of the pelvis. With the cosmetic pencil draw a horizontal line just above the uppermost lateral border of the right ilium. Cross this mark at the midaxillary line, which extends from the armpit down the side of the torso. Exhibit 3-9 shows the measurement site correctly marked for the waist circumference.

3. **Take the measurement:** Extend the measuring tape around the waist. Position the tape in a horizontal plane at the level of the measurement mark. Use the wall mirror to ensure the horizontal alignment of the tape. While the examiner remains on the SPs right side, the recorder will come around to the SPs left side to check the placement of the tape. Check that the tape sits parallel to the floor and lies snug but does not compress the skin. Always position the zero end of the tape below the section containing the measurement value. Take the measurement to the nearest 0.1 cm at the end of the SPs normal expiration.

4. **Record the result:** Call the result to the recorder, who will enter this number on the ISIS screen. Remove the tape measure. Tell the SP to let down the gown shirt and proceed to the skinfold measures.

Exhibit 3-9.
Abdominal (waist) circumference mark

Exhibit 3-10. Measuring tape position for abdominal (waist) circumference



3-16

Figure 4-5 Landmark demarcation from NHANES (2007) anthropometric survey report Source: NHANES (2007)

Country	Year	Demographic and socio-demographic infomation gathered	System used	Body undertaking survey	Amount measured or scanned	Number of measure-ments taken & if landmarke	Contact	Survey Published	Purpose of survey	Ref
Australia	2002	Adult women ranging from 18-100 years of ages with the average at 49 years. (Henneberg, Ulijaszek, 2009)	Manual measurements only. All measurers were trained in standard Martin's anthropometric technique and in taking garment-relevant measurements according to the International Standards Organisation document 8559 (1989) (Henneberg & Veitch, 2005).	The National Body Size and Shape Survey of Australia was conducted in 2002.	1266	More than 60 dimensions were measured, including weight, stature, length, and width of body segments, circumferences of trunk, head and limbs, and triceps, subscapular, and abdominal skinfolds (Henneberg, Ulijaszek, 2009).	Daisy Veitch, SHARP Dummies Pty Ltd., 102 Gloucester Avenue, Belair 5052, Australia E-mail: daisy@sharpdummies.com.au	Survey procedure and some statistics published through Henneberg & Ulijaszek's study on the relationship to BMI and skinfold thickness.	Civilian survey aimed at improvement in apparel sizing standards.	Henneberg, & Ulijaszek, (2009), Henneberg & Veitch (2005)
Bulgaria	2007	Male and female between the ages of 30-40 years.	Not specified	Bulgarian National Science Fund (TH-1407/04)	5290 (2435 males and 2855 females)		Gergana1973@gmail.co. (G S Nikolova) ytoshev@imbm.bas.bg (Y E Toshev)			
China	2004-2006	children and young adults (aged 4-17)	Lectra's 3D measurement solution *	China National Institute of Standardization (CNIS)	20,000		Jean-Louis Heyd, Lectra's worldwide project manager			

Table 4-8 An example of the Anthropometric Survey table (Activity 11)

Because information concerning 3D bodyscanning anthropometric surveys was not as detailed as that of manual anthropometric surveys this research deduced that the non-contact anthropometric survey process itself was not always transparent. Bougourd and Treleaven's work (2014) acknowledges that reporting of 3D bodyscanning anthropometric surveys may be scant on information concerning the validation of the collected data as discussed in section 2.6.3. However this research compared both manual 3D bodyscanning anthropometric reports using the works of O'Brien and Shelton (1941); Lohman (1988); Kemsley (1957) and the NHANES Anthropometric Procedures Manual (2007) against that of the reports from the international surveys listed in the Anthropometric Survey table (Appendix A), which went further than that of Bougourd and

Treleaven (2014) and found a lack of transparency within 3D bodyscanning anthropometric reports in the following areas:

- Landmark definitions were not explicit due to their algorithmic nature
- The number of scans taken per person was not detailed
- The validation process of the scanned data was scant or more often non-existent

Furthermore:

- Out of the 26 surveys reviewed for the Anthropometric Survey table (Appendix A) 23 used 3D bodyscanning technology
- Only 7 out of the 23 non-contact anthropometric surveys published explicit reports of their results and protocols
- Of these 7 non-contact surveys only 4 offered a report of the results and protocols for free
- Of these 4, only 2 were available in English (the other 2 only available in Japanese and Korean)
- The remaining 3 surveys only provided the opportunity to view the results for a licence fee
- The remaining 16 had no clear record or report of the process or the results

Table 4-9 below indicates that important information is either missing, omitted or viewable for a fee, which makes it difficult to establish how accurate the results of each survey actually were.

Country	Survey Title	Published protocols /results	Fee to view	No fee to view
China	China National Institute of Standardization (CNIS) (2006)	No		
France	Institute Francais du Textile et de l'Habillement (IFTH) (2006)	Yes	Yes	
Germany	Bra Project (1999)	No		
Germany	E-Tailor (2001)	No		
Germany	Project Elderly Women (2002)	No		
Germany	Size Germany (2008)	Yes	Yes	
Germany		No		
Italy	CAESAR (2002)	No		
Japan	AIST Research Institute of Human Engineering for Quality Life (2003)	Yes		Yes Written in Japanese
Korea	Korean Agency for Technology and Standards (2004)	Yes		Yes Written in Korean
Malaysia	University of Malaya, CRYSTAL research Institute, & University of London (2009)	No		
Mexico	CONACYT, the National Council of Science and Technology (2004)	No		
Netherlands	CAESAR (2000)	No		
Sweden	Anthropometrics of the Swedish workforce (2005)	No		
Spain	IBV & Spanish Association of Designers (2008)	Yes		Yes
Spain	IBV (2007)	No		
Sweden	Anthropometric survey for product and workplace design (2008)	No		
Thailand	Size Thailand Initiative (2008)	No		
UK	Size UK (2001)	Yes	Yes	
UK	Shape GB (2009)	No		
USAj	CAESAR (2000)	No		
USA	Size USA (2004)	No		
Canada & USA	CAESAR (2000)	Yes		Yes

Table 4-9 International anthropometric surveys: number of published results and ease of access to results

4.1.2 Experiential learning of the scanner and the creation and deployment of the conceptual model (Activities 8 and 12)

Five sources of data was used in the development of the conceptual model. Data from (Activities 9 and 10 Objective [1], and Activity 11 Objective [2] within *Table 3-2*) all three survey tables and their accompanying findings presented and discussed in section 4.2 and section 4.1.1 above were used to inform the content and the assemblage of the conceptual model.

Practical observations whilst learning how to use the TC² scanner (*Figure 3-1, Table 3-2*: Activity 8, evidence of which can be viewed in Appendix AH) was collected during the experiential learning of the 3D body scanner. This data also informed the development of the conceptual model with particular regard to the semi and automatic landmarking portions of the model (*Figure 4-15*). The field notes were handwritten notations which were written various places - in notebooks, on participants scan printouts and on loose sheets of paper and were numerous and informal. They were not intended for publication and on occasion contained sensitive information such as user names, passwords, technician and participant details. As they were not intended for publication, selected images of them are shown in Appendix AH as a way of referencing their existence for the reader. It should be noted that Experiential learning of the scanner (Activity 8) took place during Objective [1] also but usage of the TC² scanner increase during Objective [2] as this research started to prepare for the 55+ anthropometric survey undertaken in Objective [3] and felt it need more practice with the technology to ensure the 55+ survey process ran smoothly.

The structure of this next section will dissect the conceptual model and present and discuss the dissected portions of the model.

Experiential learning of the bodyscanner (activity 8, *Table 3-2* and *Figure 3-1*) signalled that knowledge and understanding of traditional anthropometric practice was fundamental to enable a clothing practitioner to apply bodyscanning technology to the clothing product development process. This research was supported by 18 years of practical experience in manual anthropometric measurement and could draw on this when comparing the newer non-contact anthropometric methods. This is because it was informed by the literature that virtual landmarking draws on and is benchmarked by traditional anthropometric methods, which use the practice of landmarking logic to determine the descriptions of start and end points for body measurements as a benchmark (cordis.europa.eu, 2007; 2.8.1). Therefore the structure of manual anthropometric practice - which is documented within the works of O'Brien and Shelton (1941); Kemsley (1957; Lohman (1988); Beazley (1997) and the NHANES Anthropometric Procedures Manual (2007) – was used as a template to document the process of non-contact measurement.

4.1.3 Anatomical landmarking process conceptual model purpose and overview

This research extrapolated from sections 2.5.1 and 2.6, O'Brien and Shelton (1941); Kemsley (1957; Lohman (1988); Beazley (1997) and the NHANES Anthropometric Procedures Manual (2007) and that of practical usage of the TC² scanner that both manual and non-contact anthropometric processes could be condensed into three areas, those being:

1	Conditions – the environment the landmarking process is undertaken in
2	Stages – the order in which tasks are undertaken
3	Tasks – what is performed by the person of software to accomplish landmark demarcation

Table 4-10 Definition of the three identified areas surrounding the anatomical landmarking process

Establishing these different areas of landmarking (*Table 4-10*) was important as it enabled this research to confirm through comparison of each anthropometric approach that manual, semi-automatic and fully automatic/non-contact landmarking practice share a very similar process.

4.1.4 The conceptual model's conditions and stages

This section will begin by presenting and discussing two areas of the conceptual model. Those being the conditions (defined as the environment the landmarking process is undertaken in) and the stages (defined as the order in which tasks are undertaken).

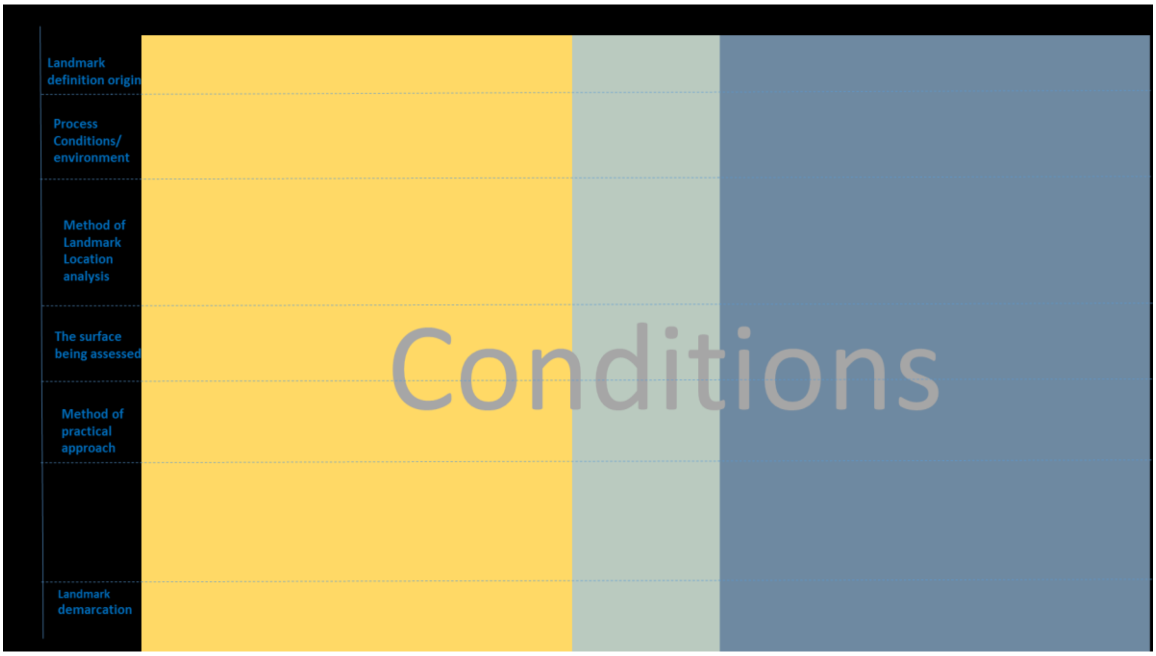


Figure 4-6 the organisation of conditions, tasks and stages within the anatomical landmarking process

The orange section of the model (*Figure 4-6*) refers to a manual anthropometric environment whereby the participant and technician both actively and practically engage with the landmarking and measurement extraction process. The blue section of the model (*Figure 4-6*) refers to the non-contact anthropometric process whereby the participant and technician are separated by the technology. The participant takes a passive role and the technician a semi-passive role in the landmarking and measurement extraction process. This research terms the technician's role as 'semi-passive' as the technician can choose the MEP to use which determines the landmarks and subsequent body measurements – thereby being partially active) but the scanner takes on fully the role of landmarking and measurement extraction. This research found nothing of this visual nature in the knowledge base and therefore determines the comparison of these areas in a model to be novel and one which contributes to the area of anthropometric measurement.

The model (*Figure 4-6*) illustrated a period of overlap (shown as a grey vertical area in between the orange and blue sections) where bodyscanner technicians, and researchers exploring its application such as Robinette & Daanen, 2006; Burnsides *et al*, 2003 – whose methods are included in the Landmarking Methods table (Appendix M) and is discussed in section 2.8.2 - demarcated participants' landmarks prior to scanning. This overlap occurred principally within the work surrounding the Caesar survey and indeed much of the data concerning landmarks generated within that survey has facilitated the work of non-contact landmarking methods and aligning template body meshes such as that of Suikerbuik *et al* (2004), Azouz *et al* (2006) and Hirshberg (2011). Therefore, this research deduced that this period of overlap allowed individuals from the fields of computer science and statistics to use these pre-landmarked scans to develop their methods thereby which supports the view held by cordis.europa.eu, (2007) that non-contact anthropometric methods are benchmarked by manual anthropometric methods.

It should be pointed out that at this stage the research found that many of the non-contact or semi-automatic landmarking methods listed within the Landmarking Methods table (Appendix M) had not been developed for or tested on women or mature women aged 55+. The methods of Suikerbuik *et al* (2004), Chi and Kennon (2006) did not test on women aged 55+. Whereas Azouz *et al* (2006) and Yoon *e al* (2009) only tested their methods on males and Burnsides *et al* (2003) study did not landmark women over 65. The Burnsides *et al* (2003) finding is particularly significant as this fed into the Caesar survey which as mentioned above has been used to bench mark non-contact anthropometric methods. Therefore this research deduced that non-contact methods which have not been validated on a female demographic aged 55+ would be prone to error.

4.1.5 The development of the conceptual model commencing with conditions and stages

The variables of manual, semi-automatic and automatic landmarking were identified from the Landmarking Methods table in row 1 (Appendix M) as both a condition and a task as indicated below in *Table 4-11.*

Conditions/Environment are coloured coded orange, grey & blue	Task = Traditional manual anatomical landmarking involving a technician interacting both verbally and physically with the participant.
	Task = Semi-automatic/contact, landmarks are located and demarcated by a technician using visual and physical examination of the skin surface. **This is the period of overlap**.
	Task = Automatic/Non-contact, whereby anatomical landmarking and measurement extraction is undertaken by software and the technician has no physical contact.

Table 4-11 Colour coded conditions for undertaking manual, semi-automatic and non-contact anatomical landmarking

The direction of the variables (in this case the manual, semi-automatic and automatic/non-contact) in conceptual models can vary (Miles & Hubermann, 1993). This research was in essence examining three different approaches to anthropometric measurement which follow a linier process. Therefore, this research's model used a vertical top-to-bottom sequential approach as this was the approach used in the literature that focused on manual and non-contact anthropometric practices (Burnsides *et al*, 2003; Sims *et al*, 2011; Beazley, 1997; Croney, 1980; Lohman, 1988; O'Brien & Sheldon, 1940; Daanen & van de Water, 1998; Gill *et al* 2014b; McKinnon & Istook, 2001). Irrespective of the condition, the process was sequential and required each task to be completed within each stage to move on to the following stage.

4.1.6 The tasks identified with the anatomical landmarking process

Portions of the literature review concerning anatomical landmarking revealed that studies of traditional (2.5.1), semi-automatic (2.8.1) and non-contact methods (2.8.2) had one or more tasks within each of its stages. This research decided to make each of the three approaches tasks easier by placing each task inside a grey box. Each box carried a directional arrow, which illustrated how the results of each respective task contributed to the flow of the each anthropometric approach as well as indicating the relational links between each approach (Figure 4-7).

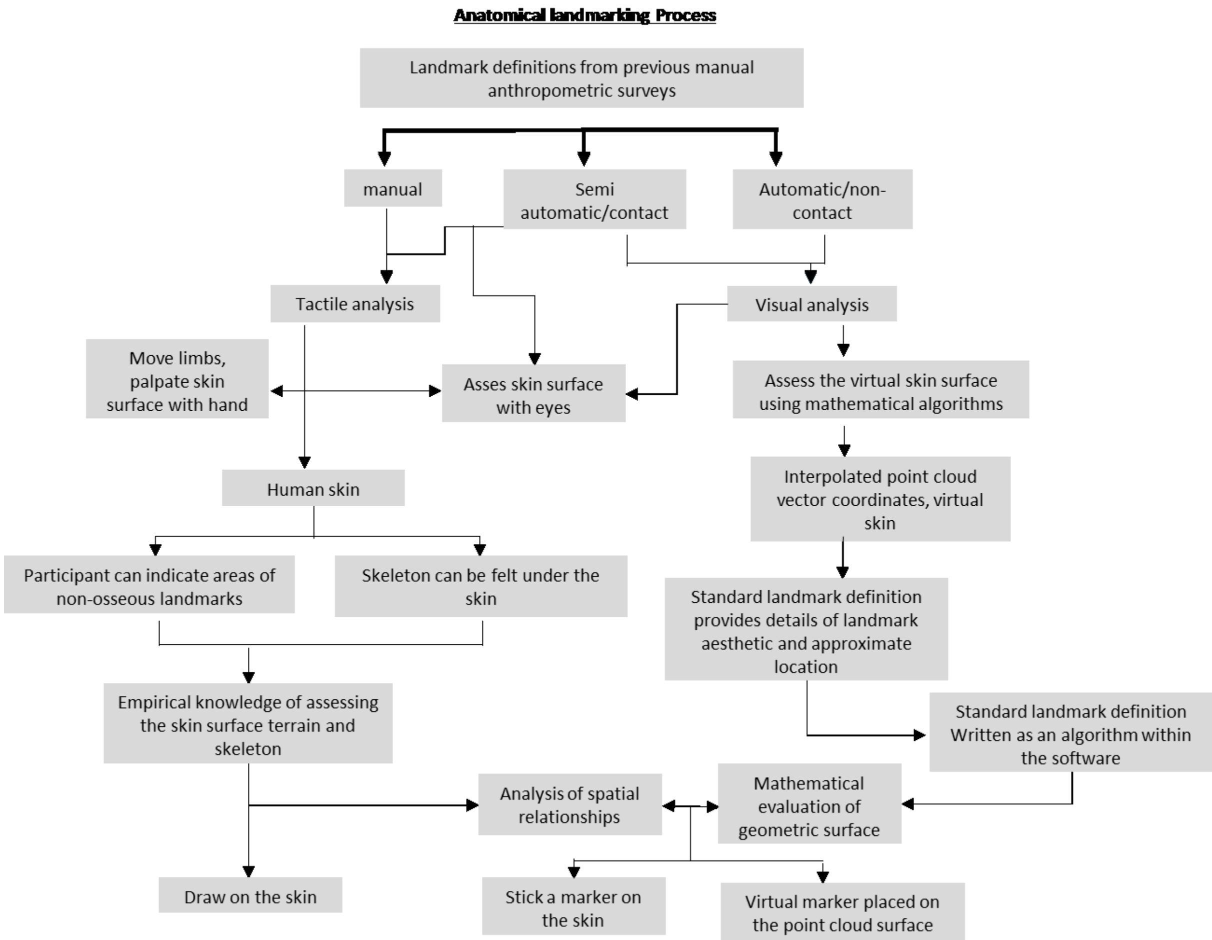


Figure 4-7 Sequence of tasks found within the landmarking process

4.1.7 Standard Linguistic definitions used to direct landmark positioning

This research already outlined that mature women undergo a series of body morphology changes directly related to the ageing process (2.3) and that these changes can mean that individuals can no longer be classified as displaying a standard body morphology. Previous work by Veitch, (2012) and Han and Nam (2011) (0, 2.8.1) indicated that generic landmark definitions are not always appropriate when applied to non-standard body morphologies.

Therefore, it is noteworthy that when this research examined the linguistics and semantics used for non-contact landmark definitions used within:

- The TC² database interface
- The Proposed Human Body Measurement Standard (Kirchdoerfer *et al*, 2002)
- BS EN ISO 20685:2010

It found that the terms remained unchanged from generic traditional landmark definitions for example found within the work of O'Brien and Shelton (1941) or Beazley (1998).

This highlights two things. The first was that not all of the landmark definitions would be appropriate when applied to a mature female whose body morphology had changed considerably due to ageing. The second was that the definitions indicated all methods of non-contact landmarking that derived from visual, tactile and/or intuitive practice, which was used to describe landmark location.

This practice of non-contact landmarking was documented as a written directive using linguistic terms and it was this directive that acted as a driver within the software (which uses a co-ordinate system) for the location and demarcation for landmarks within the automatic landmarking process (Appendix AB). As a result, this study found a strong relationship between the written directive and the areas of manual, semi-automatic and automatic (non-contact) methods. This is the strongest relationship in the model and this is indicated by the use of a heavier black line in *Figure 4-8* below. The relationship travels one way from the written directive to the three methods of landmarking.

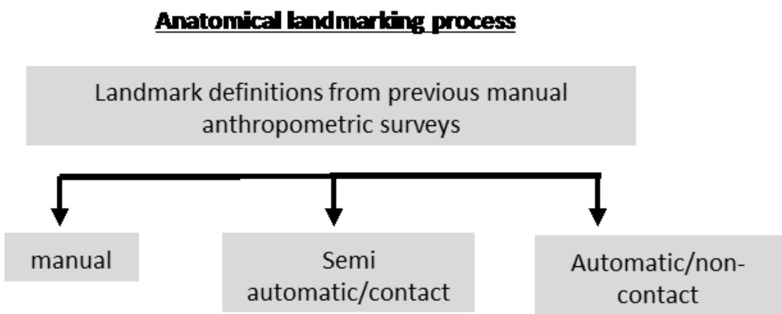


Figure 4-8 Strongest relationship within the conceptual model

Turning briefly to the 55+ scan survey, this research found that landmarking errors were clearly evident when viewing the initial few scans of the 55+ scanning survey directly after the scan had been captured (*Figure 4-9*) which support the earlier deduction that non-contact methods not validated on a mature female demographic would be prone to error as outlined at the end of section 4.1.4. For example, *Figure 4-9* illustrates two waist landmark definitions: the small of the back with a 4cm tolerance and the narrowest indentation of the torso. This research sought to use the small of the back with a 4cm tolerance as it was comparable to the definition used in the SizeUK survey and that survey had not indicated any difficulties with said definition within the small amount of information it published. When it became apparent that this definition was unsuitable, as it placed the waist at the under bust, the narrowest indentation of the torso definition was used to see if the waist placement improved.

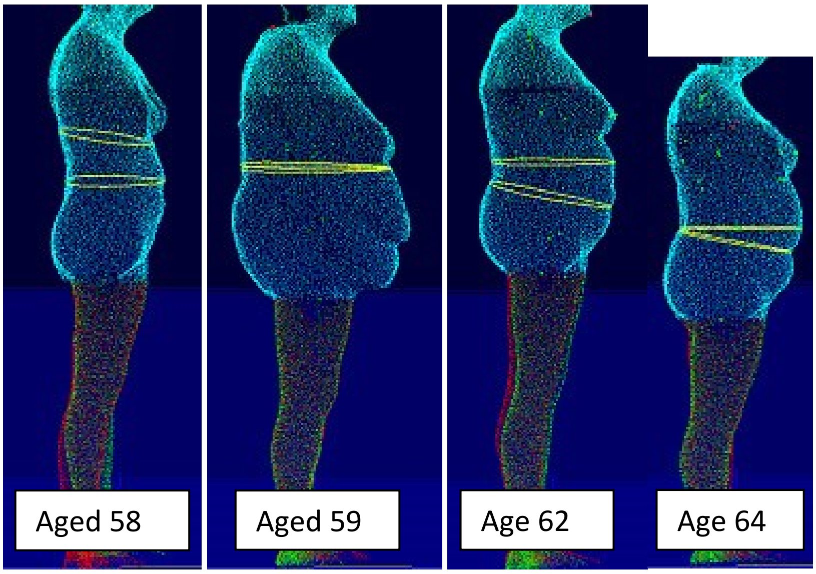


Figure 4-9 Two waist landmark definitions: small of back (horizontal) and narrowest indentation (pitched)

The research also found that definition of 'narrowest indentation' for waist location was also inappropriate as it pitched the waist at various different angles (which is difficult for making mass produced patterns) and placed the waist anywhere between the under bust to under the abdomen around the high hip area.

Neither definition shows suitable constraints to maintain measurements within an area understood to be where the waist would occur for clothing purposes and could not take into account current wear preferences – i.e. low-rise or high-waisted.

These findings will be further discussed later on in this chapter in the section headed 'CDVELA results' but is briefly mentioned now to illustrate that landmarking error can be quickly identified – i.e. straight after a person has been scanned by quickly viewing the image on screen – if the clothing technician had the appropriate anthropometric knowledge and skill set whilst operating the 3D bodyscanning technology.

4.1.8 Modification of the landmark definition to change its positioning

It was found using the information from the 3D Bodyscanner Hardware and Software Overview (Appendix H) that a limited number of commercial scanners - 7 of the 23 scanners reviewed in Appendix H, see *Table 4-12* - allow modification of landmarks using alternative landmark definitions. Previous research discussed in section 2.8.3 had already explored this using laser-based technology, in particular, the Cyberware 3D-bodyscanner, but no published study to date has explored white light or IR light-based technology using the TC² 3D-bodyscanner. It was also found through practical examination of the TC² scanner that it's database interface was limited to writing landmark definitions for only some of its landmarks as not all its landmarks can be moved or have their definitions modified, and that the methods prescribed within the Landmark Methods table (Appendix M) can only be used with specific scanners or a third party software, such as Polyworks, in much the same vein as Ashdown and Na's (2008) method.

Cyberware
Hamamatsu
Human Solutions
Inspeck
Polhemus
TC²
Telmat Industrie

Table 4-12 3D bodyscanner brands which allow user interface for anatomical landmarking

This research outlined in the literature review that previous manual anthropometric practice – that of Patterson & Warden (1983) and Woodson and Horridge (1990) - has had to modify its landmarking and measurement-taking methods to accommodate a 55+ female demographic body morphology as the methods and landmarks are based on a standard body morphology (2.5). Therefore, this research concluded as non-contact landmarking is benchmarked against that of manual the same would apply to non-contact methods. Yet unlike manual anthropometric practice, any landmark or measurement extraction modifications would have to work within the limitations of the TC² system.

4.1.9 Landmark location analysis

Returning back to the conceptual model, the next stage of the model contained the analysis of the body surface as shown in *Figure 4-10* below. All methods of landmarking utilise some form of 'visual' analysis of the body's surface, whether it be a technician using their eyes or the software calculating the coordinates/vertices and evaluating curvature of the virtual/mesh/point cloud surface. However, this is where the similarity between the different landmarking methods ends as automatic methods work on virtual surface which is not tangible and whose accuracy is governed by the configuration of the hardware and the accuracy of it calibration and manual methods accuracy is determined by skillset of the technician.

Manual and semi-automatic landmarking approaches use human engagement with the participant's skin surface whereby the contours of the skin surface are visually evaluated, physically palpated.

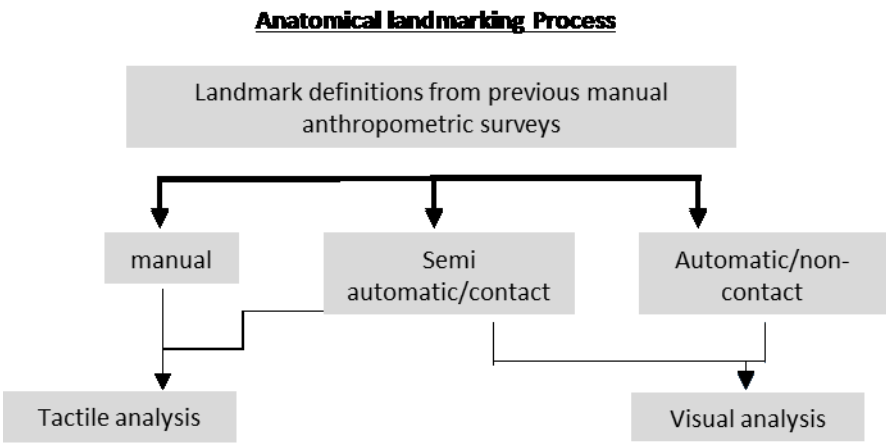


Figure 4-10 The different approaches to landmark location analysis

4.1.10 Practical approaches to landmarking

The next stage of the conceptual model assembled the practical approaches applying landmarks to either the actual or virtual skin surface.

Data from the Landmarking Methods table (Appendix M) indicated that automatic landmarking, can use statistical calculation, template matching or sliced joint junctions through spatial analysis as discussed in section 2.8.3 of the literature review chapter. This research via the Landmarking Methods table found these to be the key practical approaches for non-contact landmarking as it is reliant on the programmed definition, which is executed using algorithms within the software (right side of the model *Figure 4-11*). The landmark markers for the TC² scanner are round coloured dots, which lie on the surface of the body model (*Figure 4-12*).

Observation of the TC² scanner screen (undertaken during experiential learning of the scanner) showed the development of landmark positioning was extremely quick (much too quick to enable a screen capture). However, the work of Sims *et al,* 2011 confirms that TC² uses template matching and observation of the TC² image processing confirmed that a Reeb graph was present for a few seconds prior to the generation of the point cloud body model.

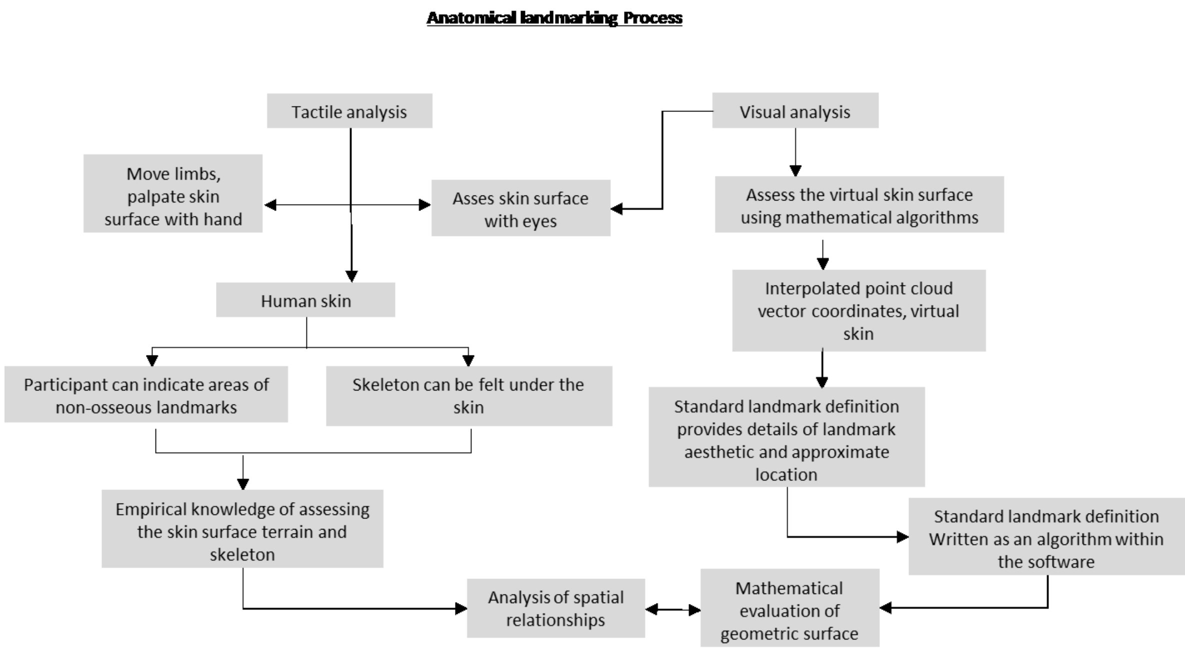


Figure 4-11 Practical approaches to landmarking

Manual landmarking methods (shown on the left of the conceptual model *Figure 4-11*) have the landmark placed on the skin surface by a technician (O'Brien and Shelton, 1941; Lohman, 1988; Kemsley, 1957, the NHANES Anthropometric Procedures Manual, 2007 and Beazley, 1997. A fully manual anthropometric approach will use a none-permanent pencil to mark the skin surface with a cross in readiness for measurement to be taken as shown in *Figure 4-13* for example. The literature indicated that semi-automatic methods demarcate in the same way but may use markers which are either cone shaped or reflective so the scanners sensors can capture them as discussed in section 2.8.2 and shown in *Figure 4-14*.

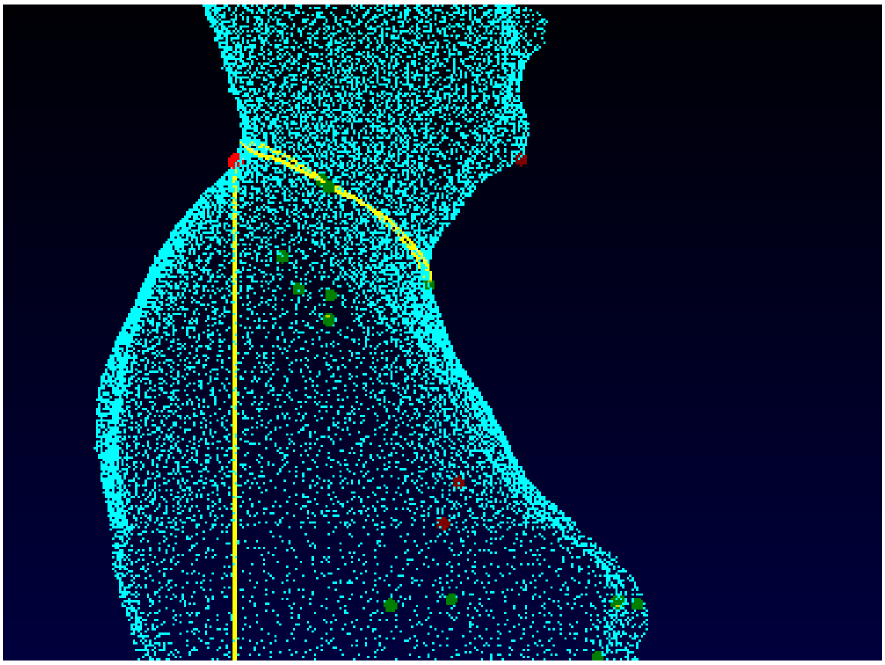


Figure 4-12 Non-contact landmark demarcation

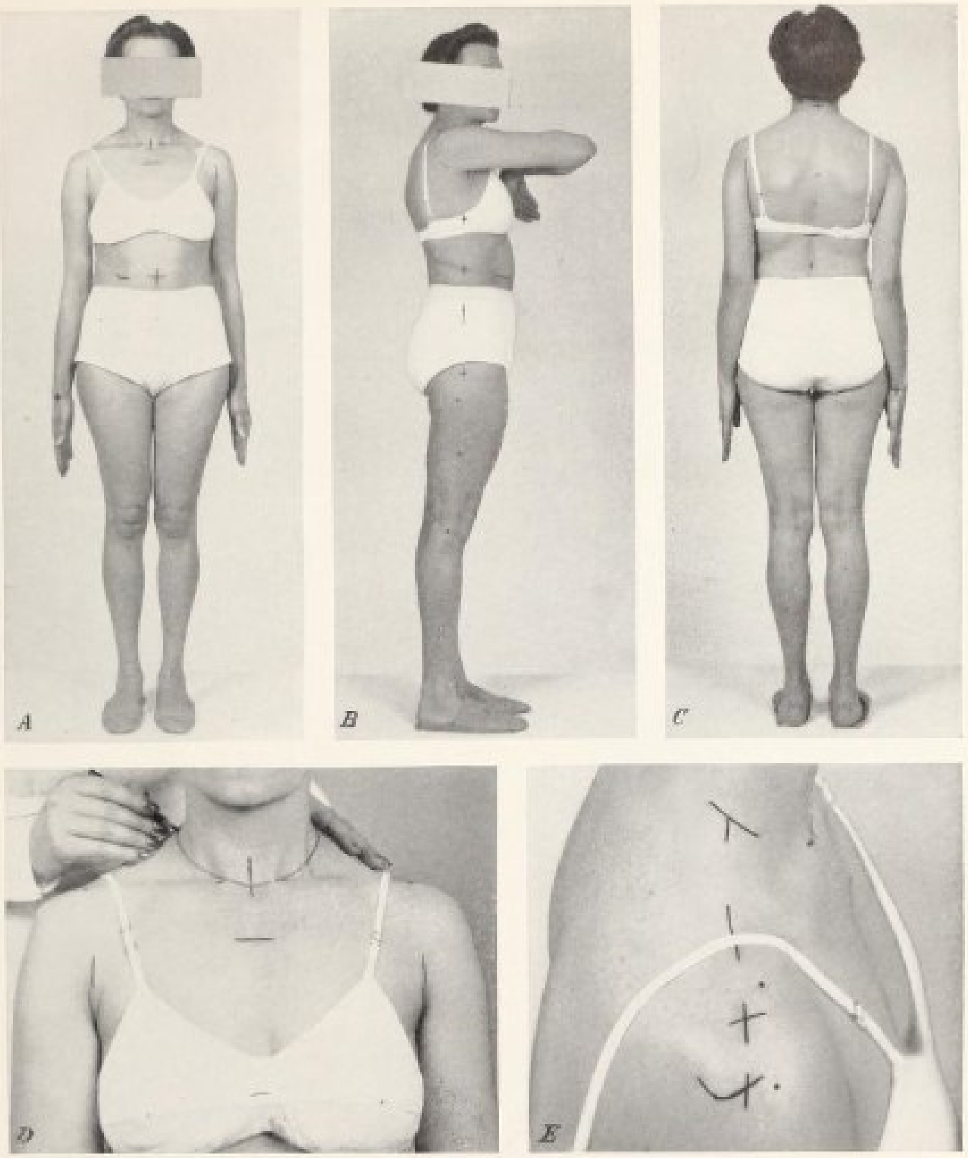


Plate 1.—*A*, Landmarks placed on the front of the body; *B*, landmarks placed on the side of the body; *C*, landmarks placed on the back of the body; *D*, position of neck chain to indicate the curve of the neck base. It passes over the seventh cervical vertebra and the medial extremities of the clavicles. *E*, Landmarks used in locating the shoulder point of the armseye.

Figure 4-13 Manual landmark demarcation Source: O'Brien and Shelton (1941)

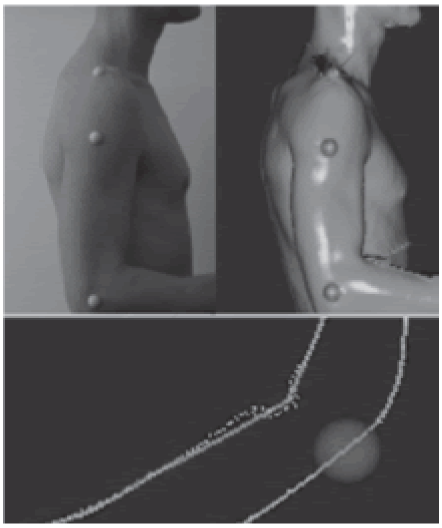


Figure 4-14 Semi-automatic landmark demarcation Source: Bragança et al (2016)

Comparing both manual and semi-automatic landmarking confirmed the potential to allow participant evaluation of the landmark location, thereby validating the landmark placement accuracy. This is a useful practice for difficult landmarks, as two individuals - the participant and the technician - verify the landmark together. This research established via comparison of different landmarking methods in the literature review, the Landmarking Methods table and the Anthropometric Survey table (Appendix A) that automatic methods differ from manual methods as the participant cannot engage with the software during the scanning process (*Figure 4-11*) and without provision for participant input valuable proprioceptive knowledge is not recorded using current non-contact anthropometric practice. Semi-automatic methods do allow and level of participant engagement as the technician liaises with the participant when sticking the markers on the participant's body prior to scanning (*Figure 4-14*). This approach though negates the privacy element of 3D bodyscanning as the participants body is seen in a state of semi-undress.

This practice does not entail familiarisation with software programming (which had already been determined by this research to be a barrier, 4.2.1) and is therefore readily implemented by a clothing practitioner. The idea of using participant proprioceptive skills gave rise to the development of the visual aid, which was placed inside the questionnaire (Activity 13). The visual aid (Activity 14) allowed engagement whilst still preserving the privacy that non-contact anthropometric measurement facilitates.

4.1.11 Landmark demarcation

This thesis confirmed through experiential learning of the bodyscanner that automatic landmarking 'mimics' manual methods by placing virtual markers on the point cloud surface (Appendix A) akin to the manner in which a manual practitioner would apply mark to the body. However, this is where the similarity to manual methods ends in the landmark demarcation phase of the model (*Figure 4-15*).

Through use of TC²'s landmark modification tool, this thesis learned that some virtual markers could not be modified without affecting neighbouring virtual markers and some virtual markers could not be modified at all whereas manual landmark demarcation allowed individual markers to be modified without affecting neighbouring landmarks. Therefore, this research was able to confirm that placement errors in one virtual marker could alter the position of other markers, which indicated that this method had the potential to impact on landmark placement accuracy, something which is not mentioned in either Dryden and Mardia (1992) or Azouz *et al's* (2006) work.

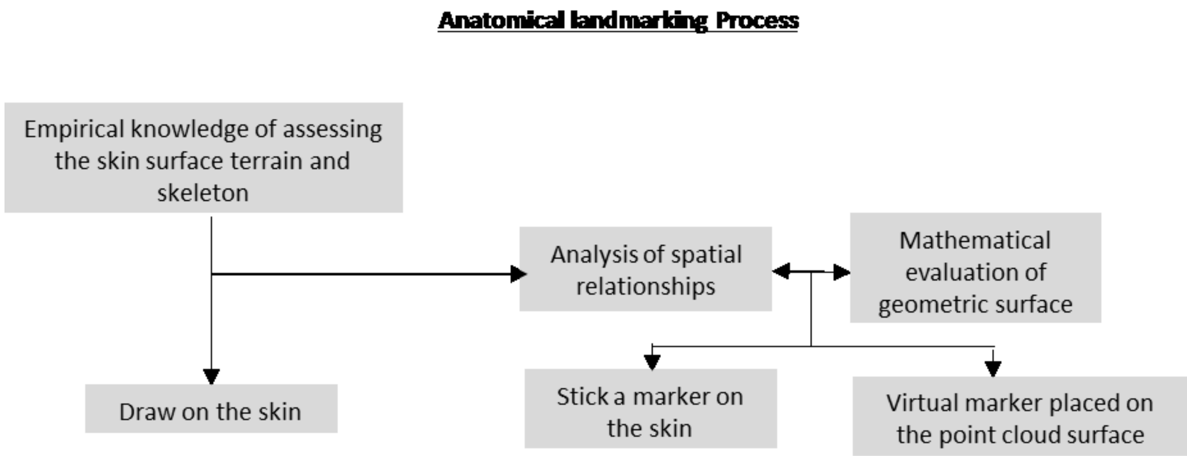


Figure 4-15 Manual and virtual landmark demarcation

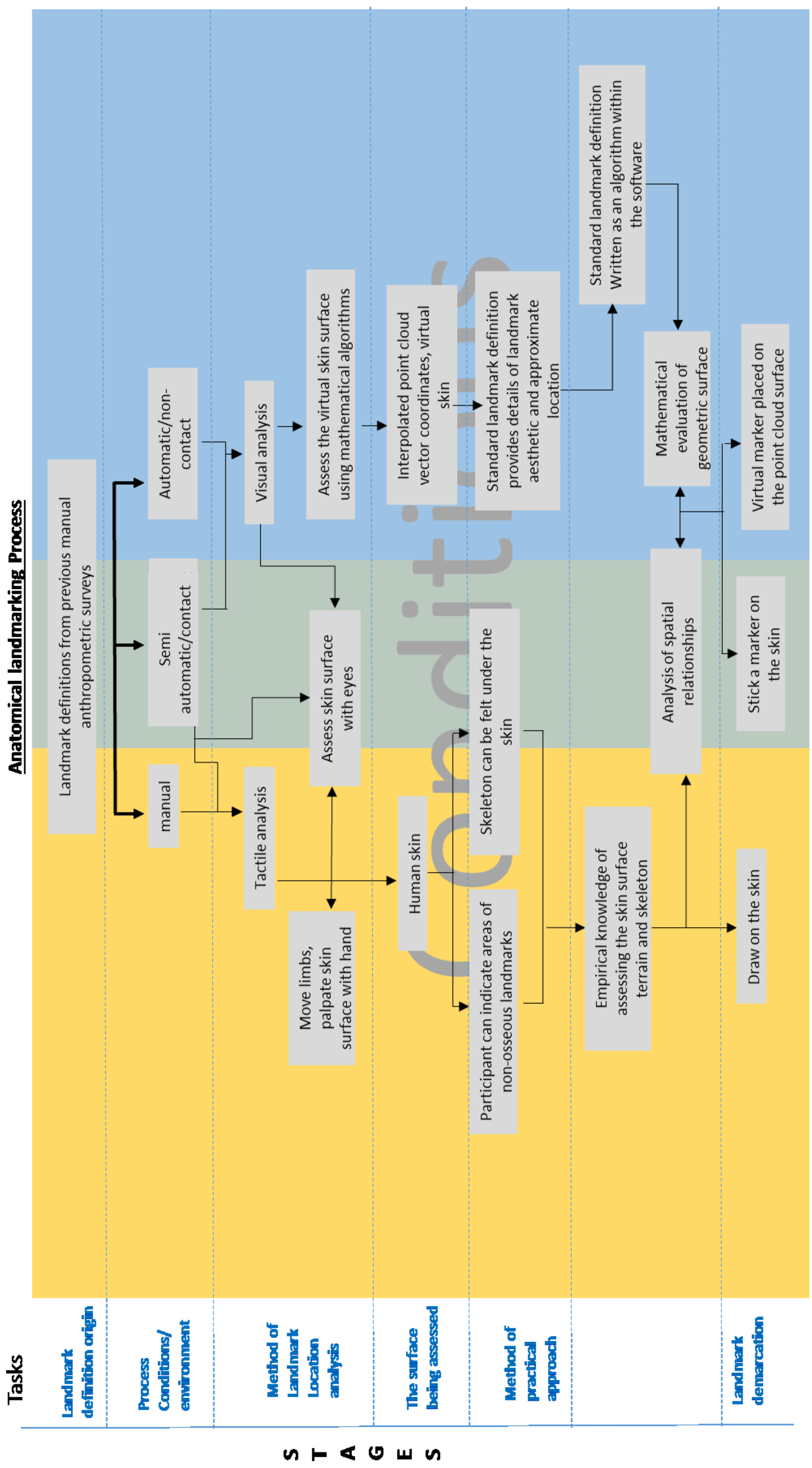


Figure 4-16 Conceptual Model for dissemination of manual, semi-automatic and automatic landmarking processes (Activity 12)

4.2 Summary for Objectives [1] and [2]

This conceptual model was developed by experiential learning of both the TC^2 bodyscanner model, in terms of its hardware configuration and software; through data gathered from other 3D body scanners hardware and software developments (Appendix G, Appendix H); and a review of the written knowledge base of manual (2.2.1) , semi-automatic (2.8.1) and non-contact landmarking methods (2.8.2). All of these sources (Objective [1]) provided the information and foundation for the development of this research's conceptual model (Objective [2]) (*Figure 4-16*).

Having the 3 approaches to body measurement mapped out for comparison gave rise to the idea that landmarking validation (via proprioception) could be undertaken by the participant - as it is done in both manual and semi-automatic methods. It would be useful to engage the participant's proprioceptive knowledge in the evaluation of their own waist position and the area in which they wore their waistbands. This method could also be developed for any other difficult to locate landmarks. However, this research identified that participant engagement needed to take a different approach to that of Robinette and Daanen (2006), Burnsides et al (2003) and Veitch (2012) whose methods (discussed in section 2.8.3) required the technician to manually stick markers on the participant's body prior to being scanning. This semi-automatic landmarking method - as shown in the grey mid-point area of the completed conceptual model above in Figure 4 10 - negated the privacy element of the 3D bodyscanning process. Therefore the conceptual model prompted reflection to see if and how participant proprioceptive knowledge could still be used in the 3D bodyscanning process whilst still maintaining privacy for the participant. This is where the idea for the visual aid began and the findings and discussion of its use and effectiveness will be discussed in section 4.4.9.

4.3 Recruitment of the 55+ demographic for the 3D bodyscanning anthropometric survey– Objective [3] results and discussion

4.3.1 <u>South Manchester recruitment - examination of the results</u>

Objective [3] was pivotal to the research question as it was this portion of the work that provided the data relating to the mature woman's body morphology for comparison with that of younger demographics (*Figure 3-1, Table 3-2*: Activities 8, 13, 14, 15, 16, 17, 18, 19, 20) . It also gathered reactions of the mature woman (via observations transcribed as handwritten field notes see Appendix AH) to the bodyscanning process and facilitated participant interaction with the scanning process using the visual aid. The field notes contain personal information about participants and therefore were not intended to be published. Their purpose was as an aide-memoire for this research and their content describes events, conversations and visual observations. Finally, the data generated by Objective [3] was used to test the utility of the visual aid in pattern/garment development and in a fit session.

The utility of this aspect of this research resulted in the publication of elements of Objective [3] in 2014 at the Lugano 3D Body Scanning Conference (the paper can be viewed in Appendix AD), where the methods and results were able to be questioned by an audience knowledgeable in both development and application of 3D bodyscanning technology. This research will refer to this publication and previous supporting studies within the discussion of Objective [3].

As discussed in the methodology, random, purposive and snowball sampling strategies as highlighted in section 3.9.5 were used for the Manchester survey, although random sampling was not as successful as the other two strategies. The method of sampling was important as the way in which a sample is gathered can have an effect on the hypothesis test and how it enables the generalising of results (Rowntree, 2000).

Recruitment of mature women aged 55 and over in Manchester was challenging as evidenced by the fact it took 4 years to recruit and scan enough women surpass the sample sizes of comparable studies such as that of Han & Nam (2011), Sims *et al* (2012) and Kouchi and Mochimaru (2011). Although South Manchester has an approximate population of 36,000 females aged 55+ (Public Intelligence, 2014), the poster campaign - which can be viewed in Appendix I and was discussed in the methodology in section 3.9.5 only managed to recruit 4 women out of 17 enquiries (which were generated via email or phone).

The field notes taken over the time of recruitment indicated women who made initial contact were curious about the research and the technology and were keen to engage verbally but expressed concerns about their body morphology, their experience of poor fit, and the lack of choice in garment styling. This finding mirrored that of Lee *et al's* (2012) work wherein verbal engagement with participants was relatively easy (2.9.3).

Reasons were sought as to why the enquirer did not want to participate further with the bodyscanning survey if the enquiry was conducted over the telephone. The gathering of this descriptive information was important as it revealed potential barriers to recruitment and provided an opportunity to address these barriers prior to advertising any scanning survey.

Past studies (O'Brien and Shelton, 1941; Woodson and Horridge, 1990 and Patterson and Warden, 1983) experienced a paucity of mature women's engagement with their anthropometric surveys (2.5.1). However, the reasons for this dearth are not explicitly explained in these studies, therefore, information regarding women's reluctance to participate in an anthropometric survey would be valuable to any study recruiting a comparable demographic. This research has reported these reasons to help academics overcome obstacles in the future.

- Reluctance to travel:

One person stated they were reluctant to travel when they realised the scanner could not be located in a place closer to their home. With hindsight, it is clear that this could be potentially deterring, particularly if the individual is elderly and has some mobility issues. At the time of this feedback, however, the NX16 model was used for scanning. As the NX16 was a fixed structure at Manchester Metropolitan University, if people wanted to be scanned they would have to travel to the university. Past non-3D bodyscanning anthropometric surveys – such as that of Goldsberry *et al* (1996) - had the potential to be more mobile and this could have contributed towards higher attendance numbers.

- Modesty:

When potential candidates came to understand that they would be required to remove outer garments some expressed concern around the issue of modesty. This concern remained even after it was explained the session would be private and the potential participant could watch a video of the scanning process via a web link to help allay apprehension.

Patterson and Warden (1983), Woodson and Horridge (1990) and Goldsberry *et al* (1996) all developed garments that would provide a level of coverage for the body but would not impact on the measurement process. However, none of these studies explicitly stated that modesty was an impactful issue on their work. Upon further consideration, this research could have been more mindful that modesty in this demographic could be an issue for recruitment, as numerous studies have indicated that women from this demographic could be sensitive about their body morphology (2.9.1). This research understood that 3D bodyscanning technology could provide privacy during the measurement process (Ashdown and Na, 2008) and was, therefore, of the understanding that using 3D bodyscanning, in and of itself, would be sufficient to counter this issue. This was not found to be the case

- Apprehension and confusion over 3D bodyscanning technology:

Some individuals were confused about the nature of the 3D bodyscanner and were of the understanding that it was a piece of medical equipment. This is, perhaps, unsurprising as other medical technology, such as Magnetic Resonance Imaging technology, shared the term 'scanner', which could explain the source of the confusion. As 3D bodyscanning technology matures in the public consciousness it is likely that this confusion could become less of an issue. However, presently it remains an issue and, as such, would need to be addressed at the recruitment stage.

4.3.2 The most successful recruitment strategies

Purposive and snowball sampling were more successful in recruiting for the Manchester survey. Women with an awareness of this research were invited to participate with positive results, making the purposive strategy successful. As these women were familiar with the person undertaking the work there was already a relationship of trust. Additionally, these participants were content to experience scanning with their friends to support them. Therefore, allowing women to bring along friends and potential participants via a snowball sampling strategy was effective. Thirty-eight women over 55 years of age were scanned in Manchester over a period of 3 years and the majority came accompanied.

Only seven members of staff from the university agreed to participate despite a university-wide email invitation, which covered all academic and administrative staff. The reasons given for non-participation ranged from a fear of other colleagues seeing their scan data or a lack of interest in body measurement information, both of which were identified in the work of Lee *et al* (2012) (2.9.3). Of the seven staff that participated four were known to the researcher. This perhaps suggests that the familiarity with the researcher and/or the research allayed any trust issues.

In summary, it appeared that women were more confident to participate if they understood the research; were familiar with the person undertaking the research; or had the support and recommendation of friends who also were willing to participate. This research found that opportunities to create these three elements within a sampling and recruitment strategy – such as advertising that friends were welcome to come along, providing talks or printed material describing the research in layman's terms prior to advertising it – has the potential to increase recruitment of this demographic.

4.3.3 Nottingham recruitment – examination of the results

Three clothing retailers were involved in the recruitment process through contact with the supervisory team. The involvement of business meant that there was a budget to spend on recruitment and to provide small gifts such as vouchers or low value fashion products as a thank you for their participation. Goldsberry *et al's* (1996) mature women's anthropometric survey was in receipt of funding, which meant they could afford to recruit further afield and that resulted in a sizable sample of 6652 participants (2.5.1). It could, therefore, be deduced that having a budget for an anthropometric survey to support promotion of the event could improve recruitment.

Promotion of the Nottingham event used the medium of radio, posters and emails to their existing client base of the collaborating businesses so details of the event were disseminated further and more quickly than the Manchester survey. This research did not play a role in answering enquiries about the event in the same way as it had done in Manchester, hence no data of this kind was captured to compare to that of Manchester.

Additionally, incentives in the form of vouchers and free products were offered to incentivise participation in the Nottingham survey, which could have contributed to more women turning up to be scanned in a shorter space of time. Forty-two women of the 55 and over demographic were scanned in Nottingham with the event taking place over three days.

4.3.4 Participant's comfort levels pre-scanning (both Manchester and Nottingham)

The field notes indicated there were no complaints from either scanning survey about the scanning experience inside the scanner booth. Fifteen women out of 38 participants from the Manchester survey stated that they viewed the scanning experience as an enjoyable event. Indeed, some participants used the scanning experience as part of a programme of leisure activity, in that they articulated plans to dine out or go shopping with friends after they had undertaken the scanning. The remaining 23 participants did not exhibit displeasure at the idea of being scanned and were neutral.

Participants came in small groups of friends and they appeared excited about the experience, with some asking if they could be scanned at a later date to check body size and shape as part of an exercising of diet regime (Wren *et al*, 2014). These responses occurred both before and after the scan process.

The survey in Nottingham took 3 days and had a busier scanning schedule than Manchester. This meant the scanning process had to be quicker to ensure shorter waiting times to avoid people leaving before being scanned. Greater numbers meant the team spent less time with individuals therefore on day two a mature woman – who had previously been through the scanning experience in Manchester - joined the scanning team to engage with the participants both pre- and post-scanning to help answer any questions and provide each participant with the questionnaire containing the visual aid. It appeared that this person put participants at ease as she reported that they responded to her in a positive manner and appeared happy to wait and fill in the questionnaire.

4.3.5 Participants comfort levels directly after being scanned – viewing the image on screen

There was a mixed reaction to viewing the scan image on the screen and it did provoke mixed emotions, as anticipated in the work of Lee *et al* (2012) and confirmed in the later work by Grogan *et al* (2015) (2.9.3). Negative emotional impact on viewing the scanned image is a significant issue as it could adversely impact participants' decisions to be rescanned and could be cascaded to their friends, preventing this avenue of recruitment too. On a more positive note, not all of the emotion reaction was negative and the majority of participants were content to see their image. However, three of the 80 women did not wish to view the image on screen and one woman asked for it to be removed from the viewing screen altogether whilst she was present.

4.3.6 Participants comfort levels directly after being scanned – viewing the print-out of the scanned image

Prior to the commencement of both scanning surveys, this research did consider using the printed scanned image complete with the measurements as the waist evaluation visual aid. However, this could only occur if the participant was comfortable with both looking at their scanned image and having a third party examine the image while they were present. Although Hollings' standard scanning process as outlined in (Appendix O) stated that participants are given a printout of their scan, Lee *et al's* 2011 study suggested that some participants could be uncomfortable viewing their image. This study confirmed that participants frequently expressed displeasure at the image when presented with the scan printout, stating that their body appeared larger/shorter than they expected and/or commenting that they were a more slender shape when they were younger. Participants appeared more focused on the scan image as comments were directed at the image (*Figure 4-17*) rather than the dimensional data down the side. However, two participants who worked as clothing practitioners complained that the waist measurements were larger than they expected with one participant measuring herself again with a tape measure to prove her point. Comments around the dimensions centred on the fact that often right and left sides of the body were different or a desire to understand which body measurements would be necessary for garment purchasing.

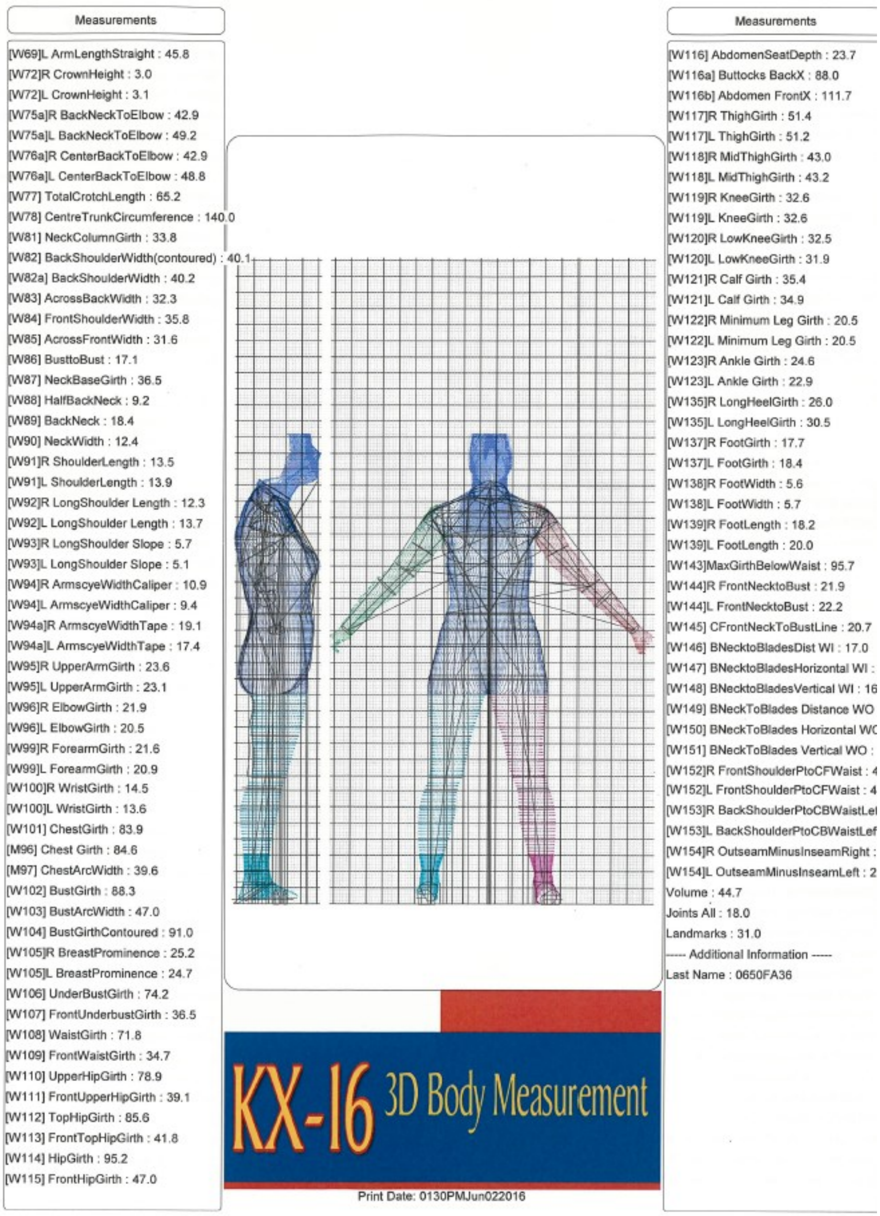


Figure 4-17 Scan print out

4.4 The results and findings from the questionnaire (which accompanied the anthropometric 3D bodyscanning survey) using descriptive statistics and discussion

4.4.1 Analysis of the qualitative data from the questionnaire, (Activities 13)

The data gathered from the questionnaire was qualitative in nature and all the responses were transcribed into a tabulated format for reasons discussed in section 3.9.8 of the Methodology. These transcriptions and their analysis can be viewed in Appendix AE and a copy of the blank questionnaire can been viewed in Appendix J. The responses were nominal, for example participants age, their clothing preferences and body areas which experience poor fit. Where possible nominal data scales were counted and a percentage of the overall sample calculated so these responses could be shown in a graphical format followed by discussion.

There were also sections in the questionnaire (questions 1, 4 and 5) for expanded comments (see Appendix J for a blank survey form and Appendix AE for the expanded responses) which were dealt with via open coding and content analysis as outlined in section 3.12.11 within the Methodology Chapter. The process of writing and re-reading the transcriptions of expanded responses enable themes to be revealed. Themes in the form of single words or phrases were either colour coded or appended with a number. The analysis of the data using colour coding and numbering systems can be viewed in its entirety in Appendix AE. However, examples of how this was undertaken is shown below in *Table 4-13, Table 4-14, Table 4-15* and *Table 4-16* below. Coding allowed the qualitative data to be quantified. Once themes were identified and coded they could be counted to show the frequency with which they appeared. This allowed the results to be shown as a chart or a graphic to present the results more succinctly, and it also revealed dominant themes within the participant's responses thereby giving insight into their ideas of appropriate and poor fit. The qualitative participant responses, are also discussed and their context is referenced using the Appendices system within this thesis. The meaning of statements can be altered when taken out of context therefore the responses were preserved in Appendix AE thereby allowing the reader to cross check for correct interpretation.

Colour	Theme
	ease of fit
	styling
	warmth
	function
	cover up

Table 4-13 Colours used to code themes associated with good fit from the questionnaire responses

I find this garment comfortable because….	Colour coding		
Trousers as I can get away without wearing tights or heeled shoes with them. Casual tops tend to be longer than blouses and I cannot stand having a gap in the middle.			
My legs are lot slimmer than my torso so trousers hide the shape of my body better and I feel more comfortable.			
I prefer to cover my legs and trousers suit me better.			
Trousers and casual tops - Of ease of movement, and when teaching, I want to make sure that I can lean across a table without revealing underwear.			
if trousers fit well I find them comfortable, warmer in winter, and can be dressed up or down to suit an occasion. …skirts are a flexible alternative to trousers and are comfortable to wear, but I find it hard to find the right sort of style, length, and fit. …casual tops often fit better, are frequently very stylish, can be made from interesting fabrics, and they often reflect fashion trends			

Table 4-14 An example of how the responses on good fit were transcribed and colour coded

Identified themes concerning poor fit				
1 waist circumference too small 1	2 front/back rise not deep enough	3 Side neck point to low hip crotch not long enough	4 sleeves too short	5 trouser length too long
6 bust too small	7 Highlights issues with posture	8 Does not conform to my body shape	9 Waist placed too high	10 sleeves at bicep too tight
11 shoulder shaping/length incorrect	12 thighs area too loose	13 Different size on top to bottom	14 waist too loose	15 sleeves too long
16 hip area too loose	17 neck circumference too small	18 styling inappropriate for body shape	19 Side neck point to low hip/crotch too long	20 hip area too tight
21 front/back rise too deep	22 Neck too big	23 Trouser length too short	24 Bust too big	

Table 4-15 Themes concerning poor fit that have been open coded using a number system

Line number	Transcription	Number code
1	My waist is high, I have to wear bigger tops because of my large bust so the tops are big on the shoulders. Jean/trousers that fit around the bottom, crotch and waist are often baggy on the thighs. Size 20 tops gape under the arm.	8, 18
2	Blouses gape over the bust. The waist is often too loose to get on my hips. Torso length is never long enough especially for swimsuits. My arms are not fat! However the sleeves are tight.	6, 18, 3, 10
3	Torso length. Hips usually too big due to my large bust size.	18, 13
4	No reply	
5	I wear separates and that helps with fit	
6	I have a large bust and tops gape open. Bodice length is too long as are sleeve length.	6, 18, 15
7	Can't fit on my waist	9

Table 4-16 Open coding and counting the themes within each participants response

4.4.2 <u>The percentage of participants who completed the questionnaire (Activities 13 and 14)</u>

The following sections starting from 4.4.2 to present the results concerning the amount of completed questionnaires as well as the content of the questionnaire responses. The format in which the results will be presented will be presented mixed between charts which can show the frequency of themes, proportion of completed questionnaires or ages who participated in completing the questionnaire, graphics which show predominate or relational links between themes, tables of percentages descriptive percentages showing garment preferences

Participant responses to the questionnaire were important as the information they allowed participant engagement within the 3D bodyscanning process to improve the positioning of their waist landmark for clothing development for Objective [3] *(Figure 3-1, Table 3-2*: Activity 14); identified particular retailers who catered for this demographic for Objective [4] *(Figure 3-1, Table 3-2*: Activities 21 and 22) and contained information which would identify areas of poor fit in a garment which covered most of the torso region of the body and determined that a bodice pattern would be the test pattern for Objective

[5] the pattern development and garment fitting stages (*Figure 3-1*, *Table 3-2*: Activities 27, 28 and 29), and. As the information fed into Objectives [3], [4] ad [5] this research felt it was essential to determine the portion of responses and discover the best method of distributing the questionnaire. This is because a high response rate means the information is representative of the population (Toepoel, 2016). A minimum response rate was not calculated beforehand as this research determined it was dealing with people and not objects and the completion of the survey was governed by the participant's willingness to cooperate. These responses are discussed directly below and presented in *Figure 4-18*.

This research calculated the percentage of completed questionnaires against the amount of questionnaires distributed. Eighty individuals (from both surveys) were given the opportunity complete the questionnaire (which contained the visual aids) and 52 (65%) women responded as shown in *Figure 4-18*. Sixty-five percent (over half) of the participants completed the questionnaire, therefore information provided by the questionnaire can be seen as representative of this population.

It was found that response rates varied by how the questionnaire was distributed. Twenty-eight participants were sent the questionnaire via email but only 9 responded. This thesis therefore found the uptake of the questionnaire was most successful when offered in person during the scanning process and for future projects will take this approach over emailed questionnaires as the face-to-face approach ensured over half of the sample responded.

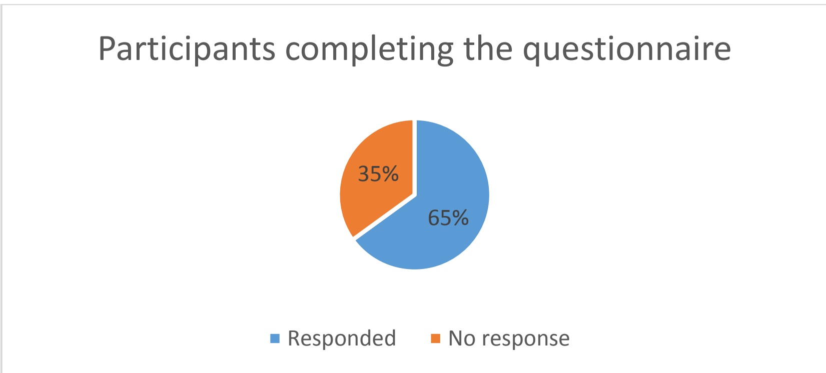


Figure 4-18 Percentage of participants who completed the questionnaire

4.4.3 The average age and garment size of participants completing the questionnaire (Activities 13 and 14)

The first section of the questionnaire took contact details, for the reasons stated in section 3.12.11, as this was needed to identify participant against their scan. They were also asked their name and clothing size for four different garment types (Appendix J).

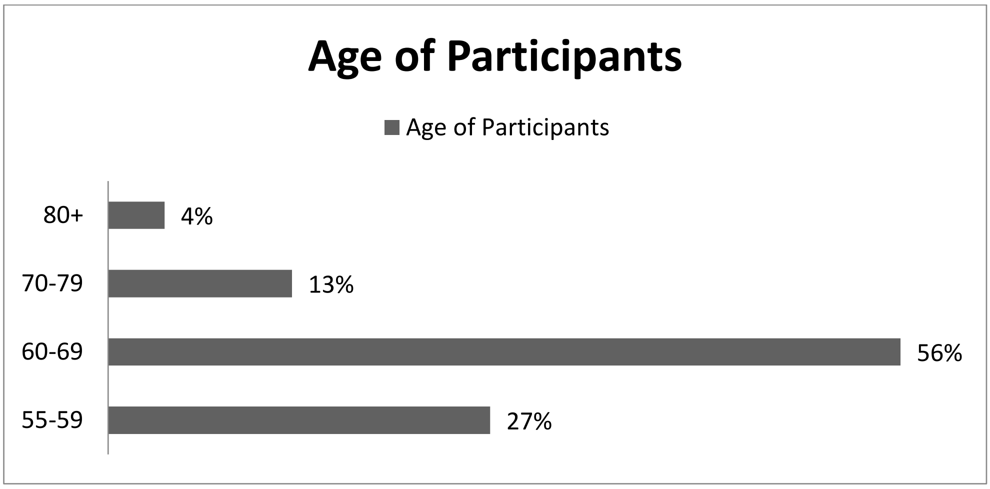


Figure 4-19 Ages of the mature women completing the scanning questionnaire

Average age of participant was a useful to know as it would confirm if using age 55 as a starting point was correct for this research. Ages were categorised starting with 55-59 following 10 year clusters of 60-69, 70-79 and then 80+. The amount of women within each age category was counted and calculated as a percentage. The average age of participants who completed the questionnaire was calculated at 65 years and the age range was 55-83 (*Figure 4-19*). This indicates many of the women who responded had already been through the menopause (2.3) and had already experienced (with varying degrees) changes in their body morphology, therefore having the age of 55+ as the starting age for this research was correct which aligns with that of the literature (*Figure 3-1, Table 3-2*: Activity 4).

Not all respondents gave their size code for the stated garments types within the questionnaire. Reasons as to why this was so were not observed nor documented in the field notes and so not reason can be offered for their omission at this time. Of those that did respond some indicated they were between sizes or that their size code varied depending on the retailer they shopped at which perhaps explains some reluctance or maybe even confusion to complete this section. If required to collect size codes from participants again this research would include a box for participants who fell between two sizes and this would be piloted to check for ambiguity. Of those that did respond size codes 10-26 were selected for dresses, 10-18 for skirts, 10- 24 for trousers and 10-28 for tops. More respondents selected trousers and tops which explains the larger variance in size code for both these garments. It also suggests that the women preferred to wear separates as different sizes can be purchased, and that there were portions of the torso, which maybe have a one or two size code difference to other parts of the torso. Literature concerning age-related body shape change indicates that different portions of the body such as the shoulders, bust and waist and overall posture experience change (2.3) and using separate garments rather than single garments which cover the torso and legs would suggest they use separates as they provide more flexibility in terms of garment aesthetic and body coverage.

4.4.4 <u>The results of participant's garment preferences (Activity 13) question 1</u>

The next section of the questionnaire sought to establish preferred garment type and perceptions of what makes a garment comfortable. This data would be used in part to determine the type of garment would be used for pattern development and toile fitting within Objective [5] (*Figure 3-1, Table 3-2*: Activities 27 and 28).

The respondents were allowed to select more than one garment to indicate what they preferred to wear (Appendix J: question 1). This was because some would choose separates and this research wanted to establish what garments were more commonly worn and if they lay on a particular part of the torso (*Table 4-17*). This information provided a snapshot in time of what garment types are popular for this demographic, something that has been done in the earlier work of Richards (1981). This kind of information is important to the clothing retailers and suppliers to the clothing industry when range planning for this demographic.

This thesis found that respondents were more likely to wear separates, in particular trousers or casual tops. This demonstrated that mature women had particular garment preferences depending on current fashions (2.5.1). The fact that participants preferred separates underlined the need to establish waist landmark definition (using participants' knowledge of their body and garment fit) for pattern/garment construction, so the style-lines and ensuing dimensions of the garment are in accord with this their requirements.

This finding gave additional purpose to the visual aid within the questionnaire as this is something which no other study had addressed indicating a new approach to body measurement for mature women.

What type of garments do you wear?				
trousers	skirts	dresses	casual tops	blouse
92%	25%	19%	90%	18%

Table 4-17 Participant's garment preferences question 1

4.4.5 Participant's perceptions of what makes a garment comfortable (Activity 13) question 1

Participants were asked what made their chosen garments comfortable as responses such as particular style lines, lengths or silhouettes can be easily implemented within the block pattern (Appendix J: question 1). Participant responses varied (as seen in Appendix AE) and open coding of the answers highlighted 5 reoccurring factors for their garment preferences. The factors were:

- Warmth
- Ease of fit
- Functionality
- Cover-up
- Styling

These factors are interrelated to each other and were, to a degree, collectively used in the participants' written responses in that a person may mention warmth and cover-up within the same statement (Appendix AE). The responses were counted and calculated as a percentage of the overall responses for this questions. This is illustrated in *Figure 4-20* below. The chart has been coloured coded with the largest factor at 32% ease of fit being brown, then styling at 26% being light blue, followed by functional at 20% being purple, cover up at 17% being yellow and finally warmth at 5% being green.

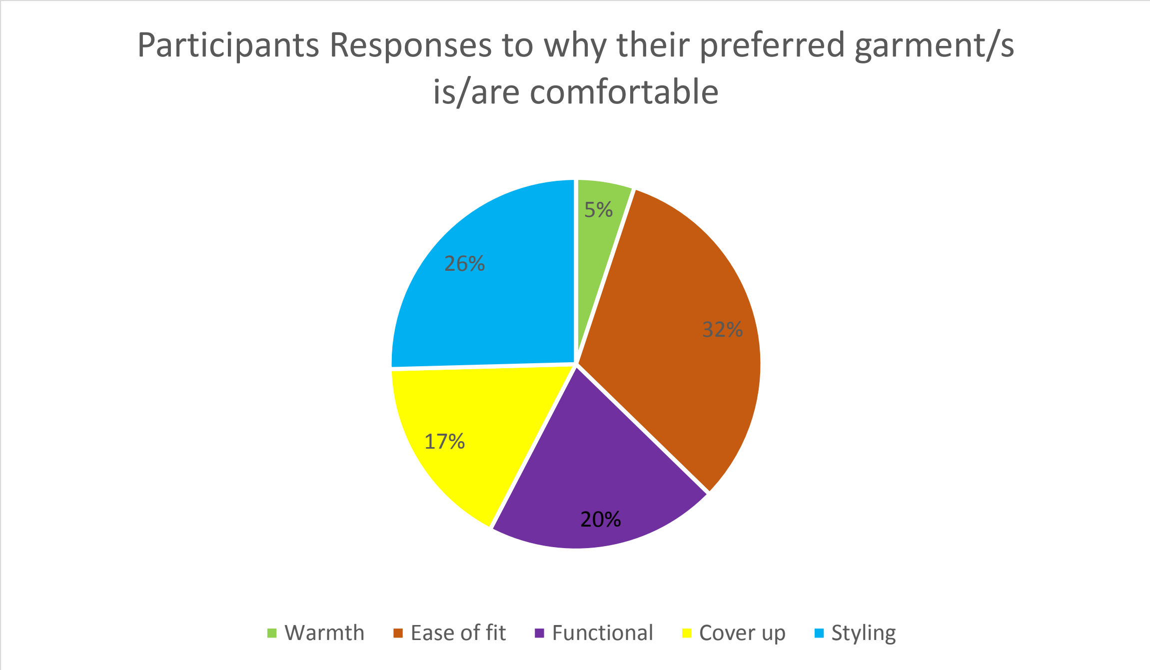


Figure 4-20 Percentage of participants' responses: perceived factors for garment comfort question 2

The percentage values appeared to be fairly evenly spread apart from the factors of ease of fit warmth at 32% and warmth which only 5% of the participants cited as a factor of comfort. As *Figure 4-20* demonstrates ease of garment fit was cited as the main factor for choosing particular garment types.

However ease of fit is a term which cannot easily be defined and so this research analysed the expanded answers to gain more insight into its meaning. The expanded answers provided more clarification and gave context to the term ease of fit. Comments such as 'Easy to wear' or 'I don't have to 'adjust' my clothing' (Appendix AE: 746) can be interpreted as indicating the statement refers to how the garment looks/lays over the body surface or how the body size and shape carries the garment (Appendix AE) which feeds into how a garment is styed and its functionality. Indeed closer analysis of the content of participant responses revealed it was also written in the same context as garment styling and garment functionality. It appeared that participants felt there was an implicit relationship between each of these factors and the following comments selected from the feedback to the questionnaire (Appendix AE) demonstrated this:

'*Loose fitting therefore comfortable'* (Appendix AE: 746)

'Trousers and casual tops are easy to relax in and still look dressy' (Appendix AE: 746)

Respondents expressed garment styling as the next most frequent factor for ensuring a garment was comfortable. Styling was also mentioned either on its own or with ease of fit alongside the factors of functionality or cover up. Comments such as: '*Trousers as I can get away without wearing tights or heeled shoes with them*. *Casual tops tend to be longer than blouses and I cannot stand having a gap in the middle'* (Appendix AE: 746), implied that trousers provided a covering for the legs while the styling of casual tops could cover the middle of the torso. The respondents' comments on garment styling used specific terms '*casual tops often fit better, are frequently very stylish, can be made from interesting'* (Appendix AE: 746) indicated that this demographic had an awareness of garment attributes and current fashion trends. This is noteworthy as it supported the findings of Nam *et al* (2006) and Rocha *et al* (2005) both of which highlighted that women from this demographic are knowledgeable about fashion and could evaluate garment attributes (2.10.2). It must be noted that both of these papers are at least 10 years old and, therefore, it is significant that this more current research found that women from this demographic continued to perceive garment styling as important when appraising the garment for its level of comfort.

Respondents' comments also proposed cover up (the ability of a garment to mask undesirable parts of the body) as another important factor in determining garment comfort. Explicit comments such as: '*I wear a skirt as my legs are too big to wear trousers'*; '*They cover a multitude of sins*'; and, '*I prefer to cover my legs and trousers suit me better*' (Appendix AE: 746) demonstrated that respondents were aware of morphological change, and if they felt negatively about their body they used clothing as a masking/corrective medium. This supported the conclusions of Güzel (2013), Hurd-Clarke *et al* (2009) and Richards (1981) as discussed in the literature review chapter (2.10.1). Although not the most cited factor in this questionnaire (it was the 4th most cited factor), it is significant as it was the factor which was discussed in the context of the person's own body and, as evidenced in the questionnaires responses (Appendix AE), produced feelings of negativity.

Garment functionality was the third most cited factor. Many of the responses indicated that the women led active lives and needed garments to function in harmony with their body's movement to provide comfort as seen in Appendix AE. Given the average age of the participant was 65 this is not surprising as according to the work of Nam *et al*, (2006) and Rocha *et al* (2005) women from this demographic are physiologically young and physically active (2.10.2).

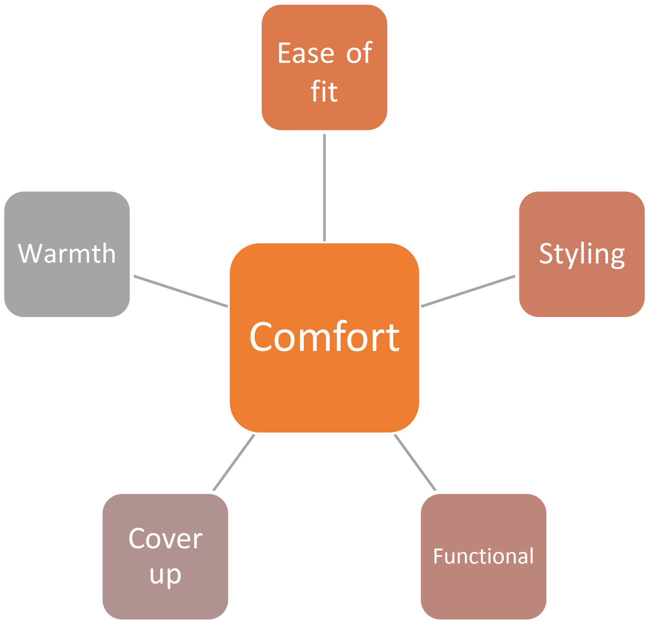


Figure 4-21 Participant perceived factors which equate to garment comfort

Participant responses such as '*[I require] ease of movement, and when teaching, I want to make sure that I can lean across a table without revealing underwear* and '*Easy to slip into and legs covered when the weather is cool'* (Appendix AE: 746), suggested that ease of fit, warmth, cover up, styling and functionality were all factors associated with garment comfort and that comfort was the main requirement from a garment. The responses from this question indicated that for a garment to be comfortable for this demographic these five factors (*Figure 4-21*) needed to be addressed alongside valid body dimensions at the design and pattern development stage. The factors of styling, cover up and ease of fit were considered against the 5 principles of fit first discussed in the work of Erwin and Kinchen (1969) and used in the work of Wren and Gill (2010) (Appendix AD) and questions around these three factors were posed within the fit pro forma (Appendix Y) for Objective [5] (*Figure 3-1, Table 3-2*: Activity 29). So for example participant would be prompted by the fit pro forma to evaluate using a Likert scale the toiles styling i.e. its suppression (line, set, ease). To evaluate the toiles level of body coverage (ease, grain, set). The toiles ease of fit in terms of its length and circumference (ease, balance, set) and its neck, armhole and waist openings (ease, line and set). Details of these findings will be presented further on in this chapter.

4.4.6 Participants reported garment fit issues (Activity 13) questions 2, 3 and 4

The questionnaire asked participants if they had any issues with any particular garments and garment fit (Appendix J: questions 2, 3 and 4) as the literature indicates (discussed in section 2.10) this is an ongoing issue for women who fit within this demographic. This was question Five garments were listed and participants could select from this list.

- Trousers
- Skirts
- Dresses
- Casual tops
- Blouses

Upon reflection, this list could have included more garments such as coats, jackets, jumpsuits and perhaps items of lingerie. However, this research's focus was not garment design and so the list was limited to generic garments that would be worn over lingerie and in doors.

The responses were counted and their frequency is shown below in *Figure 4-22.*

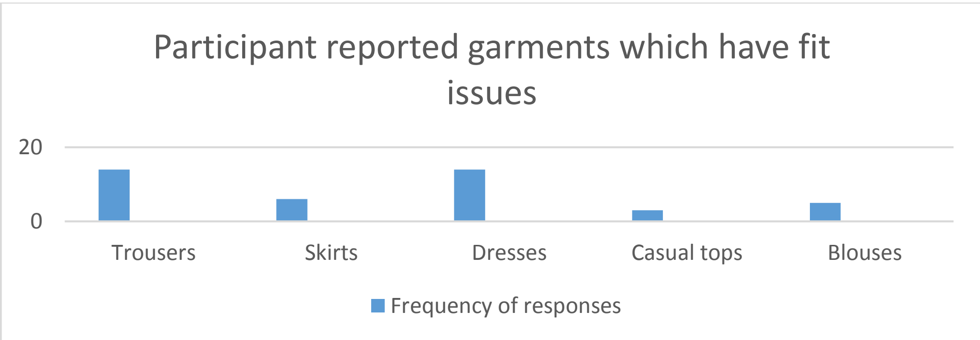


Figure 4-22 Reported garments which have fit issues question 2

The questionnaire (Activity 13, Appendix J: question 3) asked participants to indicate which garment they had found problematic for fit. The column chart above (*Figure 4-22*) shows participant's responses indicating which garments they felt more frequently had fit issues. It was surprising that participants selected trousers as having equally the same amount of fit issues as a dress given that 92% of the sample (as shown in *Table 4-17*) stated that trousers were their preferred garment to wear.

Question 3 asked participants using the images and labelled body attributes/categories provided in the questionnaire (Appendix J: question 3, *Figure 3-4)* to indicate where they found these garments did not fit them. This approach meant the responses were put into predetermined categories (of nominal data) allowing this research to count and calculate the frequency of each body attribute/category as illustrated in *Figure 4-23* below.

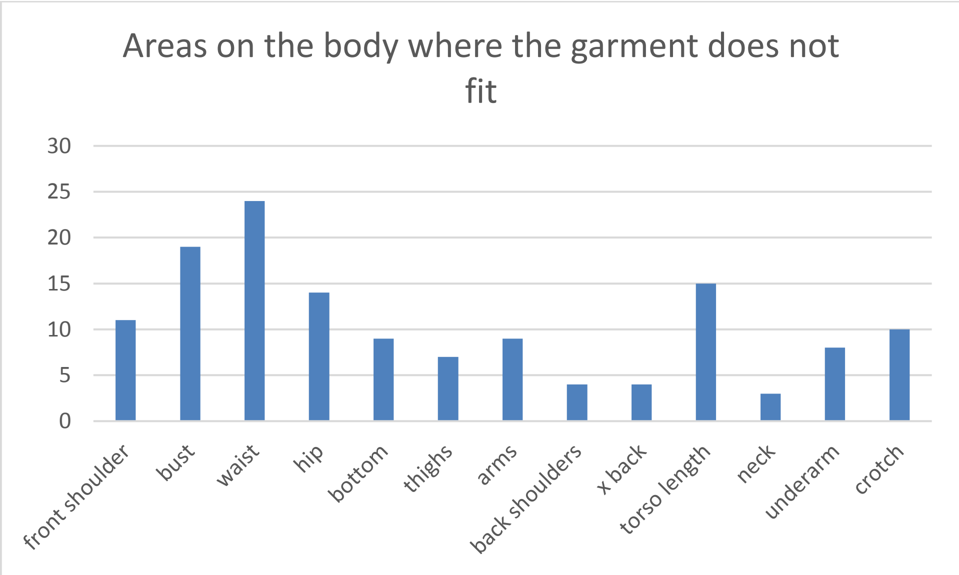


Figure 4-23 Participant identified body region where garments frequently do not fit question 3

All, with the exception of one person, chose more than one area of the body from the visual. Literature concerning age-related body morphology change outlines that the sight of most change is in the torso region (2.3) whereby women gain weight (particularly around the abdomen region (2.3.3), lose height and their posture alters. This theses findings corresponds with this as respondents cited the waist as being the area most difficult to fit followed by the bust, torso length and hip (*Figure 4-23*). This finding again reinforced the use of the visual aid as allows for waist placement modification. It also indirectly indicates that the waist circumference or depth on a bought garment is incorrect which correlates to Twigg's (2015) findings in that retailers cut garments for a more youthful body size and shape.

4.4.7 Participants perceptions of poor-fit (Activity 13) question 4

To understand the context of the poor fit in relation to their own body, participants were asked to expand on their answers using short statements or descriptions (see Appendix J: question 4 and Appendix AE for full context). These responses were rich in detail and varied and so were open coded for themes and then these themes were counted as explained in in section 3.12.11 to show their frequency. The results of the frequency of themes are presented in the bar chart below (*Figure 4-24*). There were 52 responses with 7 being either no reply or neutral answers concerning garment fit. Whereas 45 participant responses expressed issues relating to the ill fit of High Street garments in the context of personal body shape and size.

The responses were varied in the terms used but many of the terms were comparable and after these responses were transcribed, they were then coded to highlight the frequency of particular fit issues against the established age-related changes in body morphology and literatures view on retailers practice (*Figure 4-24*).

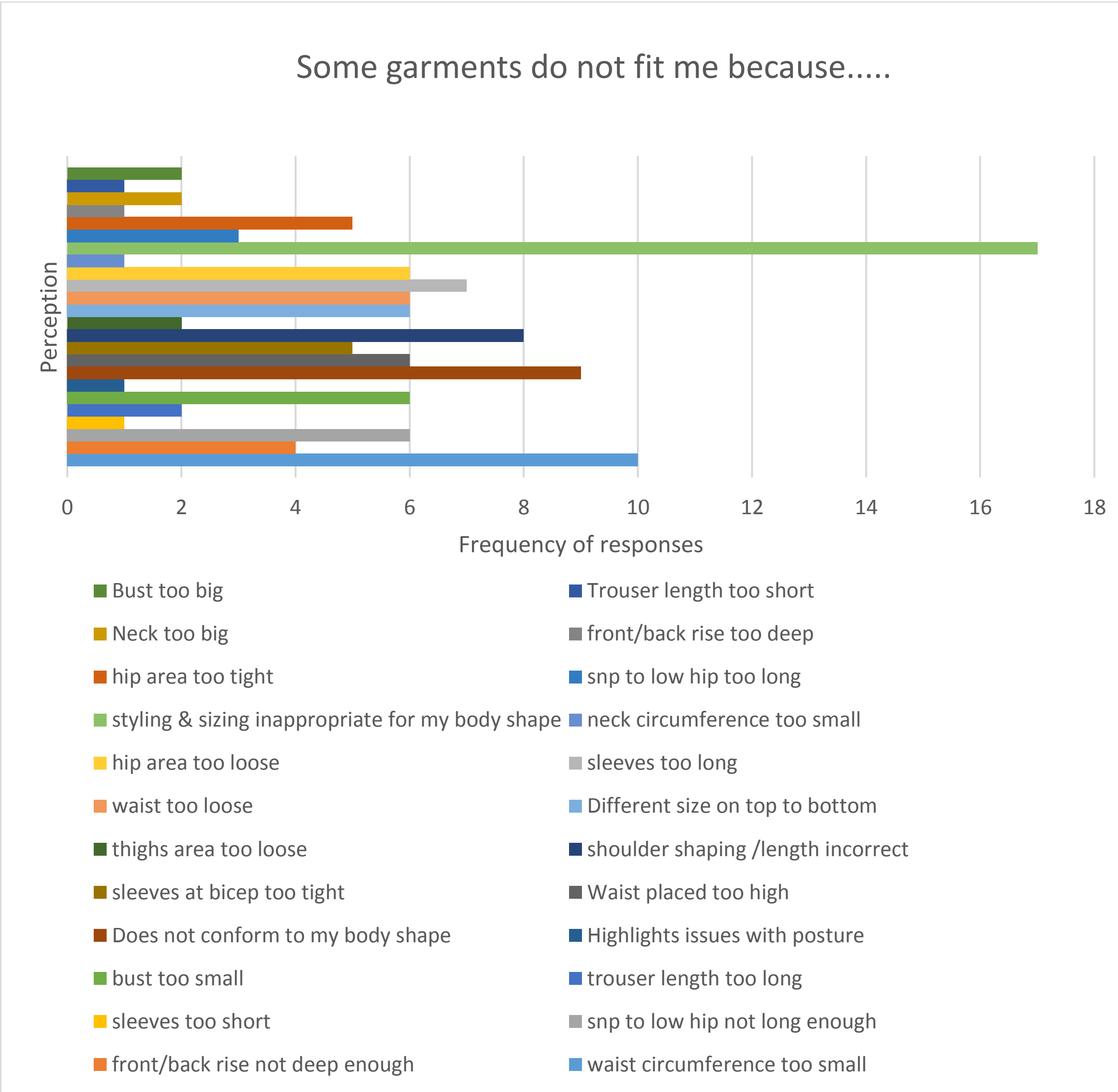


Figure 4-24 The frequency rate of participants perceptions for poor fit in garments question 4

The common perception throughout all the responses was that garments were both sized inappropriately and that the styling was unsuitable for the requirements of the participants as highlighted in *Figure 4-21* by the longest green line. This confirms previous research centred on sizing and fit discussed in section 2.10 for this demographic and indicates the problem is still ongoing and is a significant issue for this demographic. Written responses within the questionnaire which support this finding included:

'*Clothes pull across my chest and if buttoned then the button gapes open. A size up in tops is big on my across back, on my bust and across my front shoulders. The waist is either too big or too small!*' (Appendix AE: 748) and, '*Dresses, if fitted at the hip and bust are too tight at the waist. Blouses, if purchased to fit shoulders and neck, can gape at the bust. - Trousers have 'ball room' at the front crotch and often the back rise is too short'* (Appendix AE: 748)

These statements demonstrated that garment dimensions were a source of frustration for participants making this research ever more pertinent. This research reflected on these statements in light of the literature and surmised that the problem could have been due to a number of factors. The first factor concerns standard incremental grading techniques that do not appear to account for changes in body morphology, such as a change in shoulder angle (Ashdown & Na, 2008, 2.3.2, *Figure 2-8*). The second factor involves clothing practitioners/manufactures not catering for or being aware of age-related torso shape change, which occurs particularly around the bust, waist and hip regions (Lee *et al*, 2011, 2.3.3). Mullet *et al's* (2001) book on grading practice confirms that as ready-to-wear manufacturers use incremental grading techniques based on statistical averages of body measurements and because of this practice, it is likely that their clothing offer will not fit everyone (2.5). So with this in mind it is important to note that this research found that issues with garment sizing were reported by the majority (45 women) not the minority (7 women) of its sample. Indicating that the size charts currently being used - many of which are informed by the data from SizeUK (2.6.1, 2.6.2) – are inappropriate for the body morphology of this particular demographic.

Participants also expressed concerns over the styling of garments highlighting that the styling of garments was inadequate and did not provide the comfort or aesthetic requirements required by the participants as illustrated in *Figure 4-21*. Responses included:

> *'Most fit me but some garments are odd shapes – just don't suit me or just strange pattern??'* (Appendix AE: 748) and,
>
> '*Trousers are frequently not long enough between the crotch and the waist and they feel very tight and uncomfortable. I dislike trousers that do not sit on the waist as I always feel as if I am losing them. Casual tops can often be too short and leave a gap at the waist and if long-sleeved they are often too short'* (Appendix AE: 748).

This was a further expression of participants' dissatisfaction. Both the work of Birtwistle and Tsim (2005) and later Hsu (2009) suggests that clothing retailers catering for a mature female demographic have used pattern blocks that reflect the body shaping of a younger women (2.10.3), which does not cater for the changes in body morphology, and consequently does not cater to the requirements of a mature female demographic. The findings of this research therefore concurs and supports both of these studies findings.

Twigg's (2015) work provides insight into the thinking of High Street retailers who cater for this demographic as discussed in section 2.10.2 of the Literature Review Chapter. Her work also reveals that altering the styling of a garment can have the effect of ageing the garment, thereby making it less fashionable, which perhaps explained why the proportions, dimensions and styling of the garments fitted and reported by this demographic are not in accord with their body size and shape. Bougourd's (2015) case study of one UK clothing retailer suggests the way clothes are developed for mature women could change through the application of mannequin development using the data from SizeUK (2.11.6). However, it should be noted that figures detailing the proportion of the entire sample constituted by women over 55+ years is to date still not freely available from Sizemic and so it would be difficult to conclude whether the data was sufficient to develop a mannequin that would represent the mature female population.

If retailers had more realistic body sizes and shapes to fit their prototype garments on, they could identify that the styling of the garment might not be in harmony with the body size and shape but only if they are aware of the comfort requirements (determined by this research *Figure 4-21*), age-related body morphology change and what constitutes good garment fit for this demographic. A variety of mannequins which were broadly representative of the demographics of this research would assist in this.

The questionnaire endeavoured to establish if the reported fit issues were a reoccurring problem for participants (Appendix J: question 5), as poor fit for this demographic had been previously identified as an issue (Ashdown & O'Connell, 2006, Lee *et al,* 2012) and research centred on the causes of and solutions to poor fit had spanned decades. With that in mind, it was rational to expect that poor fit has been addressed by retailers and that were fit problems to occur for this demographic these would be sporadic instances addressed through continuous improvement and not something which reoccurred as a matter of course. The pie chart in *Figure 4-25* below shows that 86.5% of participates (a significant proportion of the sample) found the fit issues were reoccurring phenomena, which indicates that the problem remains and is ongoing. Therefore, this research posits that research focused on anthropometric practice, which allows engagement from this demographic (using both a questionnaire and visual aid), is the way forward to both improve and monitor garment fit.

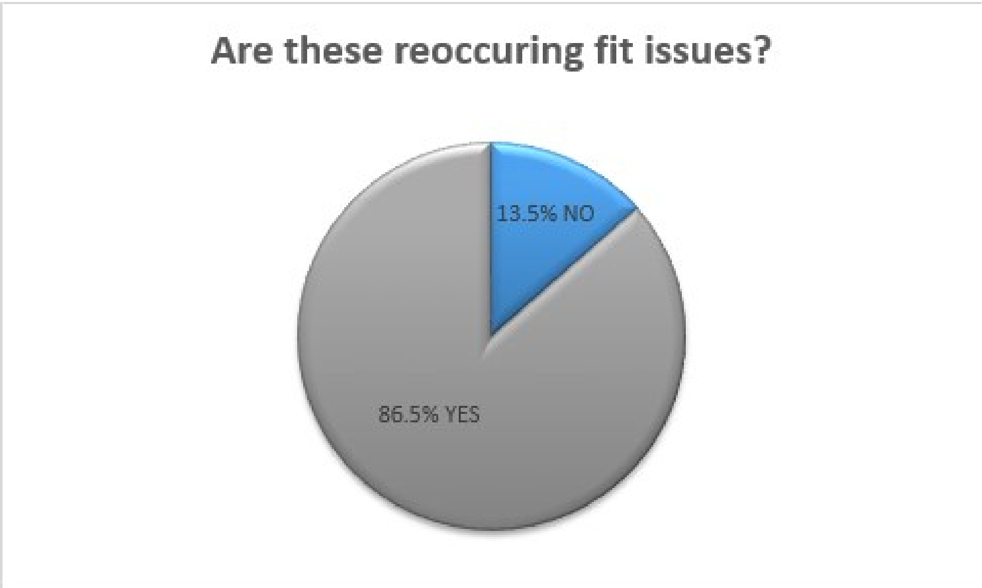


Figure 4-25 Percentage of women who found poor fit was a reoccurring issue question 6

4.4.8 Participant's preferred clothing retailers (Activity 13) question 6

The questionnaire sought to establish where participants shopped for clothing (Appendix J: question 6). This would determine if participants were shopping at a retailer who specifically targeted their demographic or if they were shopping in stores whose target consumer was younger and, therefore, provided garments for a younger body morphology. The list of preferred clothing retailers gave a foundation for the list of retailers for the measurement guidance survey undertaken as a part of Object [4] (*Figure 3-1, Table 3-2*: Activity 21) which will be discussed in the next chapter of this thesis.

The questionnaire had an expanded area where participants could list any clothing retailers they regularly or preferred to shop with. The list of retailers were transcribed by this research into a table and each time that retailer chosen by the participants was counted to show how the most mentioned retailer as indicated in *Table 4-18*.

Retailer	count	Retailer	count	Retailer	count
M&S	28	Hobbs	2	Boden	1
John Lewis	10	Whitestuff	2	TKMaxx	1
Debenhams	6	Outlets	2	Rackhams	1
Charity Shops	5	Matalan	2	Ambrose Wilson	1
BHS	5	Zara	2	Phase Eight	1
independent,	4	Romans	2	Seconds shops	1
Littlewoods	3	River Island	1	Bonmarche	1
ASDA	3	Hollister	1	Dunnes	1
Catalogues	3	Kaliko	1	Primark	1
Tesco	3	Jaeger	1	Brown Thomas	1
Wallis	3	Lands End	1	Mango	1
Next	2	East	1	ASOS	1
Fat Face	2	Coast	1	Jigsaw	1
Topshop	2	The White Company	1	Karen Millen	1
Monsoon	2	ISME	1	Reiss	1
Rohan	2	Evans	1	Klass	1

Table 4-18 Participants preferred retailers and a count of how many times the retailer was chosen question 6

Once the table was complete, this research examined these retailers' websites to determine if they catered only for this demographic as part of the commencement of Objective [4] (*Figure 3-1, Table 3-2*: Activity 21). This was done using the criteria outlined in the Methodology Chapter shown in *Figure 3-22*, and discussed in section 3.17.2, where by:

- Size charts did not contain exceptionally small sizes such as a size 4 or 6
- The models used to promote the garments looked mature
- The garments were styled or accessorised in a more classic manner

The results of this will be discussed in the next chapter of this thesis as this forms the discussion for Objective [4] which as mentioned above in 4.1 has its own chapter. Returning to the participant's preferred clothing retailers, the variety of responses indicated that women shopped in both own brand (i.e. Whitestuff, Hobbs and Matalan etc.) and department stores (Debenhams, John Lewis and Rackhams etc.), and all bought ready-to-wear garments which, as mentioned previously, are most likely sized using standard grade increments based on an average body size (Mullet *et al*, 2001). In addition, many of the participants selected retailers that had participated in the SizeUK anthropometric survey which used 3D bodyscanning technology. As SizeUK was a large-scale study (2.6.1) it could be expected that these retailers target consumer and size chart information would have originated from the scan data collected by the survey. Both the work of Lovato *et al* (2009) and van Stralen *et al* (2003) already indicated that the scanner hardware struggled to capture accurate skin surface information and to create accurate body models from individuals who did not display standard body morphology (2.7.4). It also highlighted that the definitions used are based on a standard body size and shape. The small amount of information freely available on SizeUK makes no mention of these limitations so it is difficult to ascertain (1) whether the survey encountered these issues (which, if their sample was truly representative is most likely did) and (2) by which means it overcame them.

It was deduced, therefore, from content of the responses that the participants who chose particular retailers perceive the retailer's clothing offer to be appropriate for them. This is noteworthy as some of the retailers – Topshop for example – would generally not be perceived as a retailer who caters for mature women given the size ranges it offers, it styling and the models it uses to illustrate its clothing offer. Most of the retailers selected by participants did cater for the 55+ years demographic and had been included in this research's survey of measurement guidance (Appendix K). M&S was the most preferred store and catered directly to this demographic with its Classic, Autograph and Per Una sub-labels. This was followed by John Lewis department store, which stocked their own label and a number of different brands – some named in the table above - in sections or concessions (Appendix AF) that catered directly for this demographic.

Interestingly, charity shops were also mentioned and as these contained donated garments it was less likely that they would have a sufficiently broad range of sizes to fit the participants of this research and this could present problems with garment fit. The same could be said for outlets for a variety of imperfect clothing items that have been identified as not being of the correct quality for the branded stores.

Some of the selected retailers were not typically associated with catering for a mature demographic – retailers such as Topshop and River Island – although the participant who selected these retailers was a size 8.

4.4.9 The significance of the visual aid (Activity 14) questions 7 and 8

The idea of the visual aid came from the themes within the theoretical framework (2.12), which then informed to the six propositional statements (3.5) and its development is discussed in section 3.9.8 of the Methodology Chapter. Previous manual anthropometric surveys specifically for this demographic have had to devise new measurement methods and tools to overcome issues of modesty and age-related body morphology change as outlined in section 2.5 of the Literature Review Chapter. The challenge for this research was to develop a tool which preserved the non-contact anthropometric process ensuring privacy but which allowed participant's to use their proprioceptive knowledge to interact with the technician and the technology to improve the accuracy of the landmarking process especially for garment development. Added to this the tool had to be 'user friendly' for both the technician and the participant to aid its adoption by industry and ultimately by education too. Therefore the development of the visual aid by this research is significant for two reasons as it enabled all of the above (details of which will be outlined in the next few sections) and it form part of a new process this research terms CDVELA which is outlined in section 3.9.5 of the Methodology Chapter.

4.4.10 The results of the visual aid (Activity 14): determining participants current waistband position question 7

The visual aid (*Figure 3-6*, and Appendix J: question 7) was shown to the sample who undertook the questionnaire. Question 7 was interesting as it asked the sample to note if they were wearing and waistband and if so where did it lie on their torso. It was noted in the field notes and in the calculated response rate that only 42 women were wearing a garment that had a waistband/line. Therefore, the response rate to this question cannot be directly compared to question 8 which ascertained preferred waistband position which did not require women to be wearing a waistband at the time. Nonetheless, the women who were wearing a waistband and who did response to the question were able to evaluate current waistband position on their body, again demonstrating proprioception and a unique awareness of garment fit in relation to their own body, which is valuable information for a clothing practitioner.

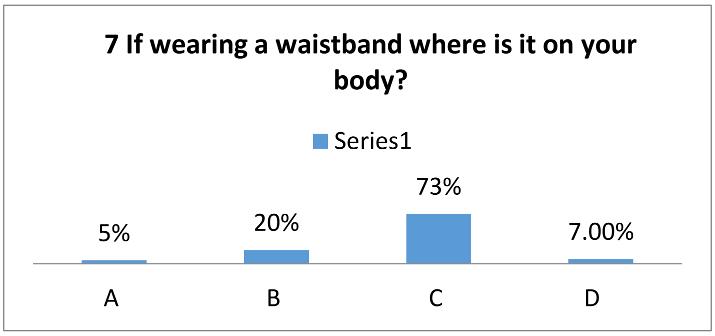


Figure 4-26 Current waistband/line positioning on the body question 7

The response indicated that 73% of participant's waistbands were positioned on the small of the back, which suggested a number of things. The first being that retailers are styling their garments differently by dropping waist-levels on their garments, up to 4cm lower than that of the most recently used waist definition used in SizeUK as seen in Table 3-5. The second being that these women could be wearing a larger size of garment so the garment is deeper and wider, falling less close to their body and enabling the style lines or waistband to appear lower on their body and anchor at the small of the back. The third being it could be that the garment waistband is worn at a pitched angle and the point of its anchor is on the small of the back

There was no information within the questionnaire to indicate whether the waistband was worn at a pitched angle. This lack of information was identified as an oversight when analysing the results of the questionnaire, especially as Veitch (2012) indicated that women who display a large abdomen may wear their waistband in this way (2.8.4). However, if the waistband was pitched then determining the angle of pitch could have proven challenging for the participant and this research wanted to ensure the questionnaire was easy to comprehend and complete. Waist angle pitch is discussed later in this research in the section discussing pattern development and toile fitting.

4.4.1 The results of the visual aid (Activity 14): where is it comfortable to wear your waist band question 8

Participants were asked to indicate, using the visual aid, where they would prefer to position their waistband/line position on their body (Appendix J: question 8). It was observed and recorded in handwritten field notes that participants performed a number of self-evaluation activities prior to choosing a visual from the visual aid (*Figure 3-5*). The next section will draw on the field notes and outline what these actions were.

Some participants:

- Palpated their torso, either in a sitting or standing position, to locate their waist
- Looked down at their body at existing garments
- Talked to their companions or the scanning staff about their thoughts before choosing a suitable visual

These physical actions are not surprising as previous research discussed in 2.2.5 and included within this thesis theoretical framework (see section 2.12) indicated that individuals are knowledgeable about their own bodies through proprioception, which often involved confirmation of one's own body portions in 3D space through movement (Kalisch *et al*, 2012).

Participants were able to indicate using the visual where they preferred to wear their waistband/line. Therefore, for this research it could be concluded that the questionnaire was able to provide information of potential waistband/line positioning for design and pattern construction, which in turn would provide a garment whose styling was in accord with the body morphology of this demographic as its development had been influenced by the responses of this demographic.

Moreover, this portion of the questionnaire, the visual aid (Activity 14), also confirmed this demographic had a firm idea of where they like to wear their waistband/line and their physical activity and verbal discussion implied waistband position is determined by ideas of comfort and aesthetics. This research suggests that these small informal physical activities (not explicitly found in any previous research comparable to this research) indicated how women evaluated the fit of their garments. Research concerning the use of visuals and participant self-evaluation of body morphology is not new (2.2.5). However, the activities used by participants to evaluate their body size and shape against a visual has not been formally recognized and documented by the current knowledge base and therefore, it is the documentation of these activities by this research that is new and contributes to the current knowledge base surrounding self-evaluation for anatomical landmarking.

Interestingly, none of the participants commented on the fact that the figures in the visual aid were depicted in profile even though the view point they had of their body was either a reflection or looking down onto the body. Additionally, no participant asked if the positions had particular landmark/points of measurement definitions. Indeed, participants did not mention these terms at all.

This is, perhaps, not surprising as information regarding anatomical landmarks or garment points of measurement are not commonplace. Therefore, through these observed activities this research concluded that subjects viewed the visual aid in an instinctive manner rather than in strictly objective manner. Song and Ashdown's (2013) work using a visual (2.2.5) did not give information on how their scanned images were shown to their participants – profile, front on, as a print out, on a screen, moving - which was important as a section of their work hinged on the women's interaction with these images. This research recognised this as a gap in knowledge and has therefore provided new insight into this process.

Each waistband position was labelled with a letter as discussed in section 3.9.8 and illustrated in Table 3-5 of the Methodology Chapter. Participants chose one letter and the total number of each letter was tallied and calculated as a percentage to shown the frequency of each waist position selected.

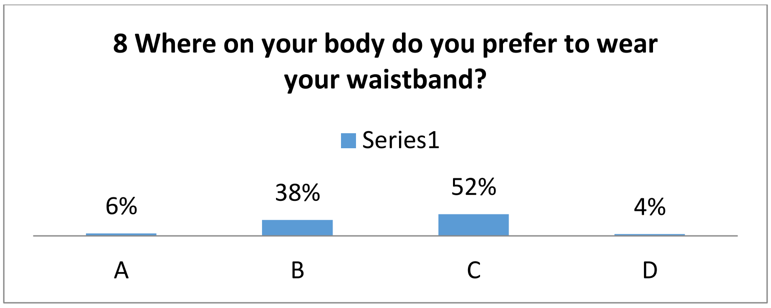


Figure 4-27 Participant preferred waist positioning on their body question 8

The column chart above (*Figure 4-27*) confirms that 52% of the sample, the highest percentage of women, identified visual C - around the small of the back – as the preferred site for their waistband position. This is an important finding for pattern development as the small of the back can be used as a natural anchor point for a garment, depending on body shape and posture, of course. Interestingly, this definition was used for the SizeUSA national anthropometric survey, a definition that according to Song & Ashdown's (2013) work (2.3.5) was inappropriate for some individuals with a fuller figure. However, their work sought to compare standard waist definitions against participants' perceptions of their waist and did not seek to find a waist definition appropriate for clothing construction, which this research as done. Therefore, their results are not directly comparable with that of this research.

Veitch's (2012) work (2.8.4) examined self-preferred waist location and concluded that this is more appropriate for pattern/garment construction and this research concurs with this conclusion. This research has gone further, in that it has developed a means to collect this demographics preferences. This makes the process novel as nothing of this nature existed within the knowledge base prior to this research.

Thirty-eight percent, the second highest percentage of women, chose visual B indicating they like to wear their waistbands up to 4cm higher than their small of the back. This is the definition used by the MMU MEP and was comparable with the UK's most recent national anthropometric survey, SizeUK. Therefore, it could be argued that this percentage of the sample would find UK garment fit appropriate, at least for waist height. This argument was tested later in the research using pattern development and a fitting session and will be discussed further on in this chapter to determine if the SizeUK definition was indeed suitable.

4.5 The application and findings of the SLVM process (Activity 17) – all age clusters

4.5.1 Written and statistical descriptions with discussion of the SLVM results

This section will first present the findings using images, written description and descriptive statistics and these will be compared and contrasted to the current knowledge base. At this point the thesis is only looking at its own samples and cannot generalise for the larger population. The results of inferential statistical testing in the form of the t-test is presented after discussion of the SLVM process which enabled generalisation of the wider population.

Fifty-two participants aged 55+, 66 participants aged 18-25 and 38 participants aged 35-45 went through the first scan landmark validation and modification process (3.11.2) which was Activity 17 illustrated within *Figure 3-1* and *Table 3-2* of this thesis. This process – termed by this research as the SLVM - (Appendix AI) evaluated the image quality of each scan, examined the accuracy of the landmarks, and how they may be modified and determined if the scan was viable. This process was published at the Lugano 3D Bodyscanning Conference in October 2014 (see Appendix AI for a transcript of the paper) whist this research was underway as it offered an opportunity for experts in 3D bodyscanning to scrutinise the process thereby establishing its validity.

4.5.2 The percentage of usable scans from each age cluster to use to test the null hypothesis and process through the CDVELA process

The results of the SLVM directly fed into the testing of the null hypothesis and the CDVELA process as it provided appropriate scan data for both. The SLVM process, undertaken by academics skilled in anthropometric landmarking, dealt with each scan individually by opening an RBD file, observing the quality of scan image and then determining the accuracy of position for each landmark based against the written definitions within the scanner landmark database. This process is illustrated in *Figure 3-7*. Any erroneous landmarks that could be repositioned to the correct area were modified using the details and instructions outlined in 3.11, and the new scan file was saved within a separate folder (3.11.2). This meant the SLVM process had the potential to eliminate some scans from the sample set which it did as shown in *Table 4-19*. This was useful as any scans that had large amounts of missing or erroneous data could skew results. Scans evidencing missing or erroneous data were removed (3.11.2).

Age clusters	Number of scans **before** the SLVM	Number of scans **after** the SLVM
18-25	66	66
35-45	38	32
55+	52	50

Table 4-19 Number of useable scans after the SLVM process

This research examined the erroneous scans as the body measurement data from these would be used to test the null hypothesis and in turn processed through the CDVELA process which could indicate if the variables of age, body size, shape or posture were the probable cause of landmark miss-location.

Each age cluster (the 18-25's, the 35-45's and the 55+) was separated at this stage (3.11.2) and as each age cluster varied in sample size (for the reasons discussed in section 3.10 and in *Table 4-19*) this research displayed the results as a percentage of each overall total rather than a total count of each age (*Figure 4-28*). Presenting the results as a percentage revealed proportional trends within each age cluster in terms of unusable scans and allowed for easy comparison between the age clusters.

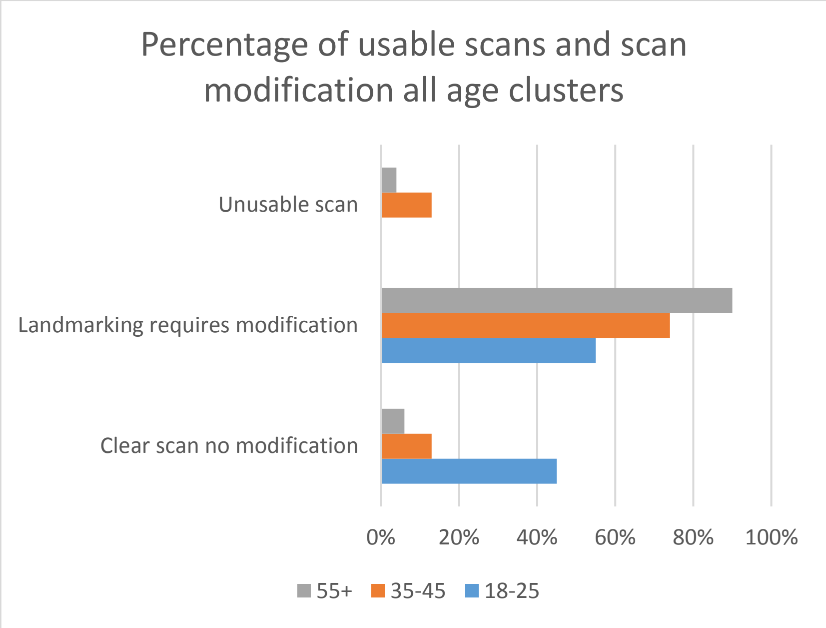


Figure 4-28 Percentage of usable scans (all ages) which would be used for testing the hypothesis and processed through the CDVELA process

Figure 4-28 above shows that the 35-45 age cluster had the most erroneous scans - 16% (6 scans) which could not be used. This was the smallest age cluster at 38 participants (reduced to 32 when erroneous or missing data scans were removed). Upon further investigation of the scan dates which are linked to the file codes, it became apparent that many of these scans were captured when the University had first acquired the 3D bodyscanner (the older NX16 bodyscanner model) and the scanner technicians were still exploring the technology, becoming accustomed to its configuration and application, both pre and post scanning.

4.5.1 Scan image error – errors due to the inexperience of the scanner technician

The 3D bodyscanning process required each participant to be prepared prior to the scanning itself (Wren *et al,* 2014). The preparation required that the participant was informed of what items to wear and remove, how to prepare their hair and how to maintain posture (Appendix O, Wren *et al,* 2014). It was apparent when reviewing some of these erroneous scans that the preparation stage had not be adhered to fully as the main error involved participant hair not being correctly tied away from the neck as in *Figure 4-30* and *Figure 4-31* below. The neck and neck base circumference measurements are used within pattern construction and would be needed in this research. Untied hair on the neck obscured the neck surface from the sensors and meant, in some instances, that an accurate neck and neck base circumference could not be extracted. Both the BS EN ISO 20685:2010 (and the earlier BS EN ISO 20685:2005) outline that hair should be tied away from the neck to reduce error. Therefore either scanner technicians' inexperience or absentmindedness of the preparation procedure resulted in poor participant preparation and scan error.

Observation of each scan image and list of body measurements within the SLVM process also identified other image errors which impacted on the landmarks and ensuing measurement readings. For example some participants were wearing clothing which produced folds over the body and flattened the breast as in *Figure 4-29* below. As the torso surface was covered by the fabric, software algorithms were unable to landmark accurately around the small of the back and these measurements could not be relied upon. BS EN ISO 20865:2010 stated that scan clothing needs to be close fitting without compressing the skin and minimal in its coverage. Again, lack of adherence to scanning preparation guidelines resulted in a scan which could not be used.

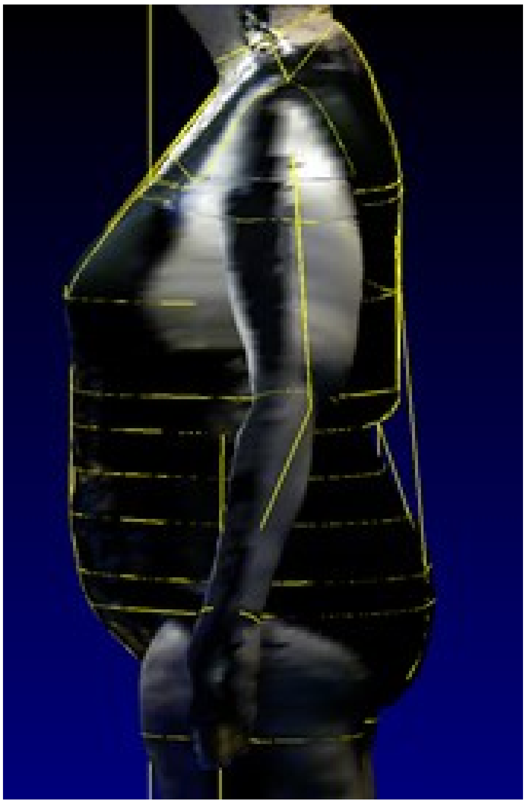


Figure 4-29 Participant wearing inappropriate clothing for scanning

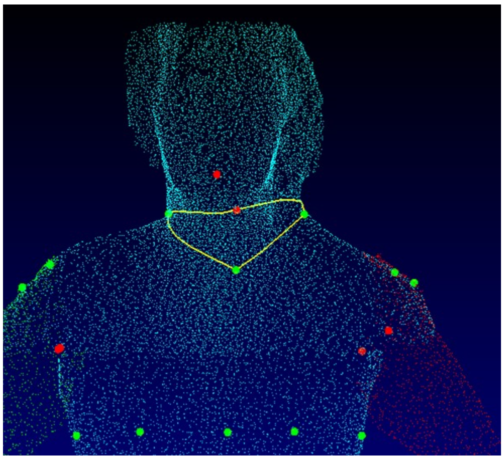


Figure 4-30 Erroneous neck base circumference due to hair lying on the neck (35-45 cluster

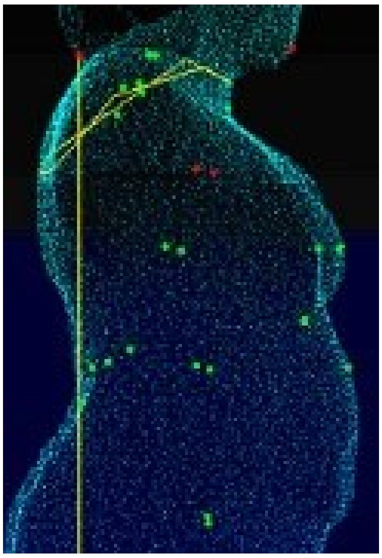


Figure 4-31 Erroneous C7/Nape of neck placement due to hair lying on the neck (35-45 cluster)

As the SLVM process requires the user to locate and open up scan files to examine them it had the potential to identify if files had been removed from the TC² system. This is because the University system separates the participant contact information from that of the scan file onto two separate pc's as a security precaution.

The SLVM process used by this research found that 2 of the scans were not present within the TC² file system. Both scan numbers were present in the scanner database (Filemaker Pro) yet the scans had either been removed or the participant had changed their mind about participating before scanning could take place. The university's ethical framework does allow for participants to withdraw at any time from the research and it was thought that in this instance the participants had exercised their right to withdrawn. As previous scanning surveys provided little detail of how they undertook their survey or information regarding their ethical framework (Appendix A) it is therefore difficult to identify the withdrawal rate from a survey, something which if known could be factored into sample size calculations and included in the BS EN ISO 20685:2010 standard.

Much has been documented about traditional anthropometric practice (Appendix AI) and how its level of accuracy in is determined by the skill of the technician (Beazley, 1997, Fan *et al,* 2004). The findings of this research indicate this is also true for non-contact anthropometric practice, whereby accuracy can be impacted by the level of knowledge the technician has regarding scanning preparation, scan capture, and scan validation which is new as nothing within the current knowledge base discusses this. Although the BS EN ISO 20685:2010 gives details on 3D scanning methodologies, the scanning preparation section is small and it does not document how the error will impact on the scan if not adhered to. The findings of this research showed scan error and through the discussion of probable cause and effect provided new insights to help avoid erroneous scans for future users.

4.5.2 Scan image error – body morphology, movement artefact and light source configuration within the hardware

The SLVM identified through image evaluation that errors for the 55+ age cluster were mixed. The images shown missing data (occlusions) due to shading issues arising from fat disposition around areas of the body where there were junctions. These junctions were the crotch or armpit points on the body where excess overhanging fat caused shadowing or where the thighs or underarm surfaces touched when the participant was standing as seen in *Figure 4-32* below.

Work surrounding the identification and occurrence of occlusions in body scans (2.7.1) for different body shapes is not new and has already confirmed that 3D bodyscanning technology had the potential to present problems when applied to particular body types (2.7.4). However, the cause has previously been attributed to the hardware configuration, the illumination technology and corpulence as noted in the work of van Stralen *et al*, 2003. No mention however has been made regarding occlusions relating to a particular demographic and the link between age and possible scan occlusion is not explicitly discussed. As this research has compared different age clusters it found that occlusions were more prevalent in the scans of the 55+ sample than that of the 18-25 or 35-45 age clusters. Therefore, this research contributes to knowledge focused on non-contact anthropometrics and their evaluation by finding that older age, and more specifically the changes in body morphology (2.3) had potential to produce images with occlusions.

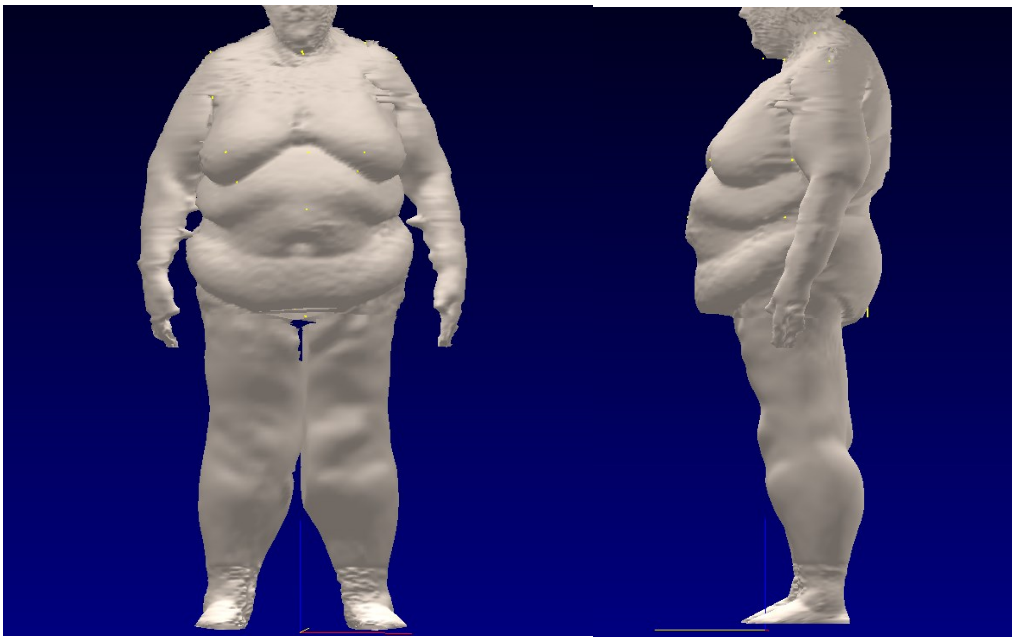


Figure 4-32 55+ occlusions due to shading at the crotch and legs touching

The SLVM process also identified that body movement artefact was another source of scan error within the 55+ age cluster. The NX16 provides handholds so participants can ensure their arms are the correct distance away from the body. This also has the added advantage of helping participants maintain their balance inside the scan booth. However, as one participant attempted to lift the handhold up and down and her right shoulder became dislocated as seen in *Figure 4-33* below. As a result, her arm lay on her torso. The scanner interpreted this as the arm being a part of the torso and wrapped the torso measurement around the body and over-arm. The dislocation and resulting pain meant that scanning was stopped and although the participant insisted on being rescanned a clear scan could not be captured as the participant was advised they should rest.

Figure 4-33 was found to be significant as the template (Reeb graph) within the software was flexible enough to place the right upper arm, elbow and forearm and in an unusual position across the torso. This can be discerned by the green point cloud which overlays the blue torso point cloud on the torso. What is notable though is that the software has no programmed algorithms which detail with limb movement in positions other than that specified by the Reeb graph/template, and in this instance even though it registered an arm (as a green point cloud) it did not attempt to give it a separate circumference measurement. This finding is significant as it illustrates that other than the static anatomical standing pose prescribed by BS EN ISO 20685:2010 and in Appendix O (which is a posture that is difficult for mature women to maintain) the scanner will not provide accurate measurements for clothing purposes. It is instances such as this which make it most important that scans are checked and validated as without these the technology cannot be deemed as either reliable or precise.

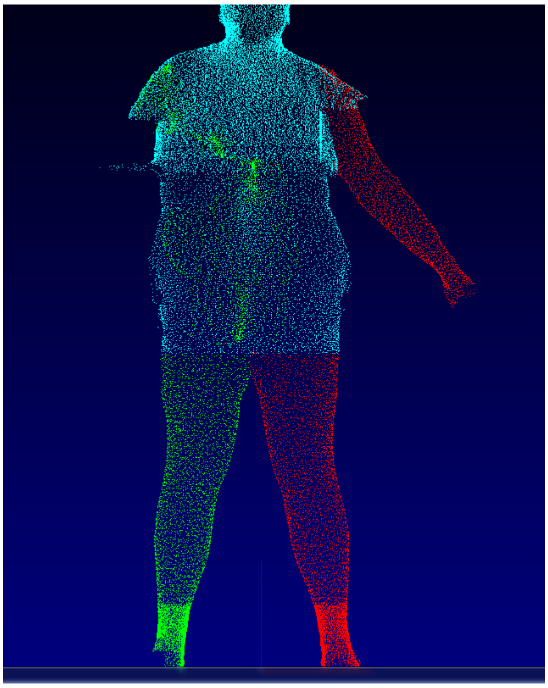


Figure 4-33 55+ sample scan issues due to movement artefact – dislocated shoulder

McKinnon and Istook's (2002) earlier work found that even small movement changes can impact on the precision of scan capture as measurement reading could vary, even at the point of respiration. This research concurred with these findings and demonstrated that larger movements could result the scan omitting limbs as well as providing greatly increased circumferential measurements to the torso or arms.

Scan errors related to body posture or stance were also identified. Participants were unable to maintain the required posture for scanning (detailed in BS EN ISO 20865:2010:

14) which stated that 'the upper arms are abducted to form a 20° angle with the sides of the torso, and the elbows are straight'.

The scanning posture was developed to allow the light source to 'illuminate' and the sensors to capture all facets of the body surface, which the software then patched together to form the body model. This is a standard scanning posture and this research found it to be rigid and challenging to maintain for older participants who could have balance or body strength issues.

Figure 4-34 below demonstrates how posture issues impacted on scan accuracy to such a degree that the scan could not be used for this research. This participant was scanned using the KX16 during the Nottingham survey. The participant had muscle weakness in her left arm and was limited as to how high she could raise her arms. Therefore, the upper portion of her arm touched her body and the measurements for the armscye, bust and waist were unreliable. As this research focused on the torso for landmarking accuracy and later pattern development, this particular scan could not be used as it did not provide accurate armscye readings. This error had previously occurred on scans captured by both the NX16 and the newer KX16 model. Which highlighted that although scanners are improving in terms of rapid scan times and higher resolution (King, 2014; Daanen & Ter Haar, 2013), unless the participant can maintain the posture prescribed by both the branded bodyscanner manual and the BS EN ISO 20685:2010 recommendations then the scan cannot be guaranteed as fit for purpose.

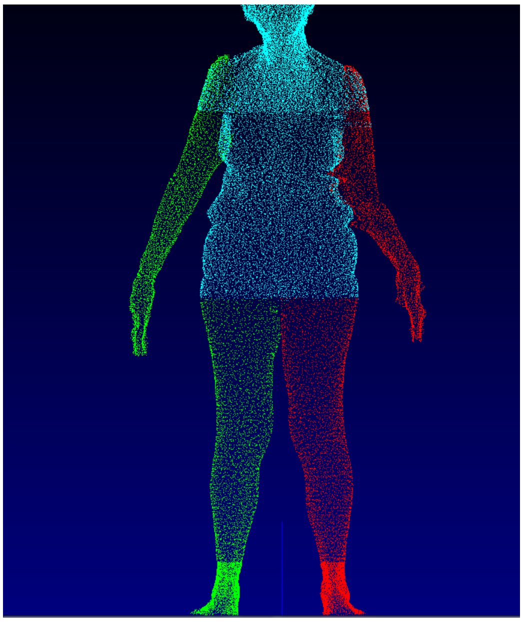


Figure 4-34 55+ sample scan issues due to posture

The 18-25 age cluster – the largest sample at 66 participants – either had scans that were issue free or required only slight modification. Importantly, the sample also contained early scans using the NX16 but body movement artefact, lack of posture maintenance or poor scanning preparation were not an issue and no scans were omitted (Figure 4-28). This meant that the SLVM process for this demographic was much more swiftly expedited as there were less issues to identify and report on for each scan. Therefore, it can be stated that scan evaluation for a younger demographic can be a much speedier process which, in an industry that can be time sensitive (Wren & Gill, 2010), could be an advantage.

4.5.3 The results of the SLVM: Percentages of landmarking errors that could be amended

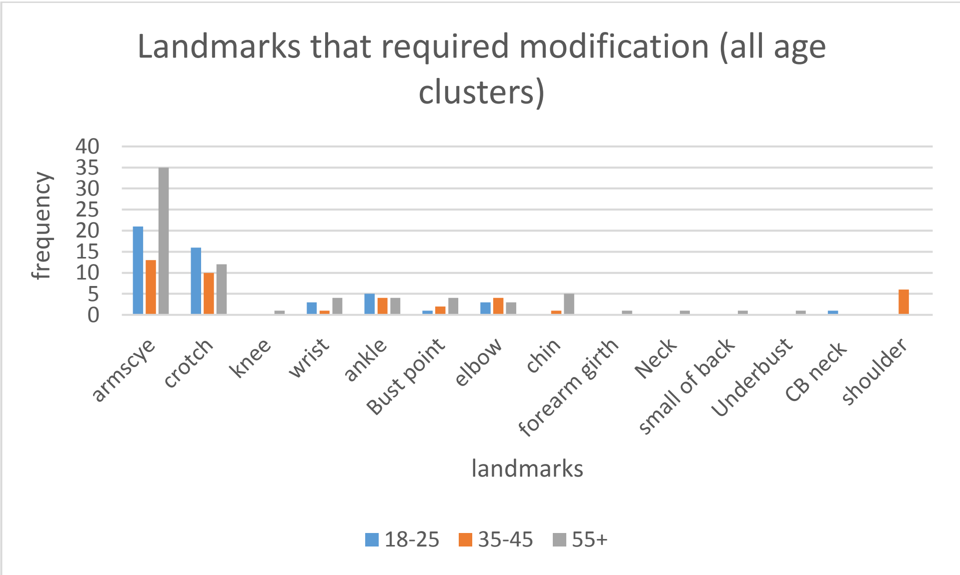


Figure 4-35 Landmark errors which have been modified as part of the SLVM process

Figure 4-35 above shows landmarking errors on places like chin and ankle. This research focused only on the torso region and as these body measurements are not required for bodice development and are not normally areas associate with age related change they not within the scope of this research and so are no discussed.

The findings illustrated in *Figure 4-35,* were significant within this research as the results not only showed the proportion of landmark error for all the age clusters, but the results determined which landmark (and in turn the accompanying measurements as the scanner does not provide landmark coordinate information within its database interface as discussed earlier in section 3.12.5) would be used within the calculations of the t-test.

4.6 The results of the t-test and the null hypothesis (Activities 19 and 20)

4.6.1 Organising the data for the t-test (Activity 19)

This research found it was difficult to at first determine which data to use for the t-test as the scanner provides body height and girth measurements but not explicitly the coordinate measurements of a single landmark. This thesis intended to make patterns from the scan measurements and traditional pattern methods do not use landmark coordinates but instead require length and girth measurements as demonstrated by the pattern measurement guidance in Appendix C. Nonetheless, this research want to test the hypothesis to either confirm or refute the null hypothesis, which would then enable generalisation of its results. With this is mind the research therefore needed to see in what way either height or girth measurement changed when a scan had been through the SLVM process as these changes would indicate an issue with the original measurement position. The SLVM process demonstrated that when the landmark was modified and that meant moving the landmark across the point cloud surface in either an X or Y direction there appeared to be measurement changes to both the height of the landmark and/or to the girth measurements it provided. These measurement values varied depending on the direction the landmark moved. For example if the landmark were moved upward in a Y direction then the height of that landmark increased and vice-versa for the opposite direction. Likewise, if for example a shoulder landmark were moved in the X direction nearer to the side neck point then the shoulder measurement would decrease in value. It was found that the difference in the original and modified measurements would give a new value which provided a quantity of landmark measurement error which this research termed 'the value difference'. Therefore the changes between the unmodified and modified body measurements were calculated by subtracting the modified measurement from the unmodified to give a value difference as discussed previously in section 3.12.3 and illustrated in *Figure 4-36* below. It should be noted at this point that this calculation was developed by this research and therefore is novel and contributes to the non-contact anthropometric knowledge base.

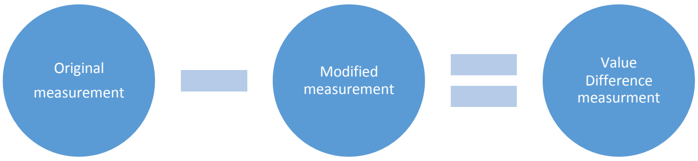


Figure 4-36 The value difference calculation to provide the data for the t-test

The value difference between the modified and unmodified scan measurements for armscye depth, armscye width, crotch height to floor, and bust girth were selected for the t-test as they were the measurements whose landmark positions with showed the most frequent errors as illustrated in *Figure 4-35*. *Table 4-20* below illustrates how the value difference was documented in Excel. An Excel formula which minus one cell from another was created within each of the value difference cells to give the value difference i.e. cells A2-B2=C2.

1	55+			35-45			18-25		
2	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	Value differenc e	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	Value differenc e	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	Value differenc e
3	85.37	110.79	-25.42	106.2	107.1	-0.9	94.1	94.1	0.0
4	114.17	136.55	-22.38	84.8	85.2	-0.3	98.1	99.1	-1.0
5	104.76	115.54	-10.78	86.3	86.4	-0.1	91.9	92.5	-0.7
6	110.79	115.22	-4.43	96.6	96.6	0.0	91.8	91.8	0.0
7	99.57	103.51	-3.94	80.5	80.5	0.0	83.4	83.4	0.0
8	103.31	105.30	-1.99	118.3	118.3	0.0	86.6	86.5	0.1
9	108.12	109.89	-1.76	99.1	99.1	0.0	90.0	90.0	0.0
10	127.29	128.79	-1.50	105.6	105.6	0.0	102.8	102.8	0.0
11	89.42	90.76	-1.34	145.2	145.2	0.0	85.6	85.6	0.0
12	108.55	109.78	-1.23	94.2	94.2	0.0	82.0	82.0	0.0
13	117.81	118.76	-0.95	100.1	100.1	0.0	83.0	83.5	-0.5
14	93.81	94.61	-0.80	107.4	107.4	0.0	87.6	88.1	-0.5
15	111.69	112.31	-0.62	97.4	97.4	0.0	109.4	109.4	0.0
16	100.33	100.83	-0.50	90.0	90.0	0.0	82.6	82.6	0.0
17	116.42	116.91	-0.49	96.8	96.8	0.0	95.4	95.4	0.0
18	100.80	101.13	-0.33	105.9	105.9	0.0	102.2	102.2	0.0
19	118.74	119.00	-0.26	99.1	99.1	0.0	87.4	87.4	0.0
20	116.39	116.63	-0.24	105.7	105.7	0.0	97.4	97.4	0.0
21	102.38	102.60	-0.21	106.6	106.6	0.0	96.6	96.6	0.0
22	103.46	103.62	-0.16	135.1	135.1	0.0	95.7	95.7	0.0
23	111.26	111.40	-0.14	98.6	98.6	0.0	86.9	86.9	0.0
24	123.51	123.63	-0.12	98.6	98.6	0.0	86.7	87.0	-0.4
25	100.79	100.88	-0.10	91.9	91.9	0.0	103.4	103.4	0.0
26	102.15	102.22	-0.07	124.8	124.8	0.0	108.2	109.2	-1.0

Table 4-20 How the value difference appeared in Excel

There were some participants who perhaps did not require a modification of any specific measurement and their value different would read 0.0 as can be seen in *Table 4-20.* As there was no change between the unmodified and modified measurements any value difference with a reading of 0.0 was removed from the data set. This was because this research wanted to include only measurements positions which had been adjusted as the amount of adjustment would be recorded in the t-test report as ‘observations’. This action mean that +/- value difference numbers were used and the data had no 0.0 values within its array as shown in *Table 4-21*. The array of numbers shown in *Table 4-21* would be copied and pasted again into a Excel spreadsheet in readiness for Excel’s t-test function.

84	55 Bust girth Value Diff	35-45 Bust girth Value Diff	18-25Bust girth Value Diff
85	-25.42	-0.93	-1.02
86	-22.38	-0.33	-0.98
87	-10.78	-0.12	-0.69
88	-4.43	-0.02	-0.65
89	-3.94	0.08	-0.57
90	-1.99	0.48	-0.54
91	-1.76		-0.51
92	-1.50		-0.49
93	-1.34		-0.35
94	-1.23		-0.21
95	-0.95		-0.02
96	-0.80		0.10
97	-0.62		1.72
98	-0.50		
99	-0.49		
100	-0.33		
101	-0.26		
102	-0.24		
103	-0.21		
104	-0.16		
105	-0.14		
106	-0.12		
107	-0.10		

Table 4-21 Value differences with 0.0 values removed

The 55+ age cluster’s value difference for armhole depth, armhole width, crotch height to floor, and bust girth was tested against that of the 35-45 and the 18-25 combined as they are the younger sample. As the two age clusters were contained different in ages (one was 55+ and the other 19-45) the t-test two sample was used. The variance within each age cluster was unknown at this point so the test for unequal variances, was chosen as outlined in 3.12.5. As stated previously this thesis used a one tailed test as the hypothesis was deemed as directional and a one tailed test is considered more robust (3.6).

4.6.2 The t-test results comparing the value difference scores of the 55+ against the 18-45 demographics (Activity 20)

The t-test results are shown in the following tables below (*Table 4-23, Table 4-24, Table 4-25,* and *Table 4-26*).

The Welch's t-test calculation is as follows:

$$\boxed{t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{se_1^2 + se_2^2}}}$$

Table 4-22 Welch's t-test calculation Source: Statisticshowto.com (2017)

The t-test as stated in section 3.12.5 questions whether a difference in values between two group's (either independent or dependant) mean scores is unlikely to have occurred because of random chance within the sample (Coolidge, 2013). The hypothesised mean for these set of t-tests was set at zero as the null hypothesis suggests there is no difference in mean between both age clusters.

The t-test calculated the actual means for both armhole depth and width showing a small difference between both armhole depths as illustrated in *Table 4-23* and a slightly larger difference for armhole width in *Table 4-24* below. These differences are were small to demonstrate that the independent variable of age is the factor which impacts on landmarking accuracy for the body regions as outlined in the null hypothesis.

The variance for the 55+ age cluster showed larger standard deviations for the armhole depth, a value of 3.91, away from the mean. The 18-45 age cluster show less spread in the variance with smaller standard deviations, a value of 1.22, away from the mean. Likewise, the 55+ age cluster showed larger standard deviations for the armhole width, a value of 7.79, away from the mean. In comparison the younger age cluster, the 18-45 year olds also showed large standard deviation values of 8.16 for armhole width. Although the variance for the 55+ shows a much greater spread in variance for the armhole depth when compared to the younger age cluster this in itself cannot refute the null hypothesis.

Concerning armhole depth, this research found there were 31 observations (incidents of landmarking modification) for the 55+ age cluster and 18 observations (incidents of landmarking modification) for the 18-45 age cluster. Armhole width had 44 observations for the 55+ demographic and 42 for the 18-45 age group cluster. This aligns with the descriptive findings illustrated in *Figure 4-35* above. Making judgments using observations alone would suggest that landmarking error is more common for the old demographic for armhole depth but not armhole width. However, observations on their own cannot be used to generalise the results or refute the null hypothesis.

The t-test for measurements involving the junction of the arm to the torso – the armhole depth and width value difference measurements were calculated using Excels automatic t-test function. The p values for the armhole depth were calculated by subtracting the alpha value from that of the Excel generated p value shown in *Table 4-23* and *Table 4-24* below. This research found that the armhole depth was 0.24 (24%) larger than the 0.05 alpha value and armhole width is 0.34 (34%) larger than the 0.05 alpha value as presented in *Table 4-23* and *Table 4-24* below. These p values mean that the value differences for the 55+ demographic for these body regions show no significant change when compared to the value differences of the younger demographic.

The next step was to align these results against that of the null hypothesis statement. Which states:

> The independent variable of age-related body morphology change has no effect on the precision of dependant variable, automatic non-contact landmarking and the subsequent body measurements, and therefore these landmarks and ensuing body measurements do not require their accuracy validating.

The results of this set of t-tests indicate the statement is partially true in that the independent variable of age is not the factor, which impacts on the precision of landmarking for this area of the body. Therefore, this research can generalise that age will not affect non-contact landmarking accuracy for that part of the body as the values produced by both t-tests for the armhole regions were not significantly different between both age clusters. However, the fact that there were landmarking errors for the younger age cluster within the armhole region suggests that landmark validation – the SLVM process - is necessary and prudent for all scans of ages of women for this body region as a means to ensure measurement accuracy for garment product development.

t-Test: Two-Sample Assuming Unequal Variances

	55+ armhole depth value diff	*18-45 armhole depth value diff*
Mean	-0.61	-0.86
Variance	3.91	1.22
Observations	31	18
Hypothesized Mean Difference	0	
degrees of freedom	47	
t Stat	0.57	
P(T<=t) one-tail	0.29	0.05
t Critical one-tail	1.68	
P(T<=t) two-tail	0.57	
t Critical two-tail	2.01	

If the P value is smaller than alpha reject null hypothesis	the P value is 0.24 larger than the alpha 0.05	**Partially confirms the null hypothesis**

Table 4-23 t-test results for armhole depth value difference for ages 55+ & 18-45

t-Test: Two-Sample Assuming Unequal Variances

	55+ armhole width value diff	*18-45 armhole width value diff*
Mean	-0.04	0.05
Variance	7.79	8.16
Observations	44	42
Hypothesized Mean Difference	0	
degrees of freedom	84	
t Stat	-0.15	
P(T<=t) one-tail	0.44	0.05
t Critical one-tail	1.66	
P(T<=t) two-tail	0.88	
t Critical two-tail	1.99	

If the P value is smaller than alpha reject null hypothesis	the P value is 0.39 larger than the alpha 0.05	**Partially confirms the null hypothesis**

Table 4-24 test result for armhole width value difference for ages 55+ & 18-45

The t-test once more calculated the actual means for both crotch to floor height and bust girth showing this time a more considerable difference in values as illustrated in *Table 4-25* and *Table 4-26* below.

The variance for the 55+ age cluster showed much larger standard deviations, a value of 4.48 spread away from the mean for the crotch point to floor. The 18-45 age cluster showed less spread in the variance with smaller standard deviations, a value of 0.91, away from the mean. The bust girth had an even larger standard deviation, a value of 28.63 spread away from the mean demonstrating a large spread in the variation. The 18-45 age cluster showed considerably less spread in variation with a standard deviation of 0.39 away from the mean.

This research found for crotch to floor that 27 observations (incidents of landmarking modification) for the 55+ age cluster and 57 observations (incidents of landmarking modification) for the 18-45 age cluster. Bust girth had 42 observations for the 55+ demographic and 19 for the 18-45 age group cluster. Making judgments using observations alone would suggest that landmarking error is less common for the 55+ demographic for crotch to floor and more common for bust girth when compared to a younger age cluster that aligns well with the descriptive findings illustrated in *Figure 4-35* above.

The t-test result for the crotch to floor and bust girth value difference measurements were calculated using Excels automatic t-test function. The p values for the crotch to floor and bust girth were calculated by subtracting the alpha value (0.05) from that of the Excel generated p value shown in *Table 4-25* and *Table 4-26* below. This research found that the crotch to floor was 0.05 (5%) smaller than the 0.05 alpha value and bust girth was 0.02 (2%) smaller than the 0.05 alpha value as presented in *Table 4-25* and *Table 4-26* below. Both p values supported the rejection of the null hypothesis; however, it would be prudent to state that their differences from the alpha value are small. The fact that the crotch point to floor landmarking can be generalised as being more erroneous when using non-contact anthropometric approaches is significant as Chumlea *et al's* (1984) early study indicates that this demographic is more likely to gain weight on the torso and not the limbs. Schofield *et al's* (2006) study also confirms that older women have a wider flatter buttocks which when combined with larger thighs can make landmarking this region of the body problematic. This research arrived at two conclusions. The first being that this study's sample had a high proportion of women with excess fat on their thighs. The survey had recruited women from the younger age range, as confirmed in section 4.4.3, the women were able bodied and their answers to question 1 of the questionnaire (Appendix AE: 746) inferred they lead active lives (4.4.5) therefore muscle atrophy and the appearance of thinner limbs did not apply to these women. The second being that the shape of older women has changed in the last 30 years (due to different lifestyle choices) and that further research is needed to investigate and document age-related body morphology changes for the younger end of the 55+ demographic.

The results and findings of this set of t-tests indicate the null hypothesis statement is false in that the independent variable of age is a factor, which impacts on the precision of landmarking for this area of the body. Therefore this research can generalise that age will affect non-contact landmarking accuracy for both the crotch point to floor and the bust girth measurements. Therefore scans for this demographic need to be checked for accuracy using the SLVM process to ensure viable measurements for pattern development.

t-Test: Two-Sample Assuming Unequal Variances

	55+ crotch to floor value diff	*18-45 crotch to floor value diff*
Mean	2.48	0.20
Variance	4.48	0.91
Observations	27	57
Hypothesized Mean Difference	0	
degrees of freedom	31	
t Stat	5.34	
P(T<=t) one-tail	0.00	0.05
t Critical one-tail	1.70	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.04	

If the P value is smaller than alpha reject null hypothesis	the P value is 0.05 smaller than the alpha 0.05	**Reject the null hypothesis**

Table 4-25 t-test result for crotch point to floor value difference for ages 55+ & 18-45

t-Test: Two-Sample Assuming Unequal Variances

	55 Bust girth Value Diff	*18-45 bust girth Value Diff*
Mean	-1.83	-0.26
Variance	28.63	0.39
Observations	42	19
Hypothesized Mean Difference	0	
degrees of freedom	43	
t Stat	-1.87	
P(T<=t) one-tail	0.03	0.05
t Critical one-tail	1.68	
P(T<=t) two-tail	0.07	
t Critical two-tail	2.02	

If the P value is smaller than alpha reject null hypothesis	the P value is 0.02 smaller than the alpha 0.05	**Reject the null hypothesis**

Table 4-26 t-test results for bust girth value difference for ages 55+ & 18-45

4.7 The findings of the CDVELA process (Activity 18)

The t-test only provided confirmation or rejection of the null hypothesis and did not provide any possible cause for landmarking error for the 55+ female demographic. Therefore, once the t-tests were complete this research sought to explore possible causes of landmarking error for the 55+ female demographic. This was undertaken using the comparison of demographics and the variables which can effect landmarking accuracy process which (as discussed and detailed in section 3.12.7) is termed by this research the CDVELA process (*Figure 3-1, Table 3-2*: Activity 18).

4.7.1 Most common age, body shape and BMI for each of the sample age clusters – analysis of quantitative scan data

CDVELA The process started by calculating the age range within the 55+ sample. This was necessary as age-related body change is gradual (Croney, 1980) and as a women ages the more pronounced the changes away from a standard body morphology may be. This is true for height as height loss accelerates after age 70 for women (Sorkin *et al,* 1999) and height loss is linked to changes in spinal architecture (Lindsey *et al,* 1980). Therefore, the research wanted to determine if one particular age was predominant within the sample as if the sample consisted of participants from the younger end of the age cluster then these age-related body morphology changes might appear visually more subtle. The research also wanted to establish the proportion of older women that participated, as previous research centered on this demographic – from example that of O'Brien and Shelton (1941) and Goldsberry *et al* (1996) recruited women from the younger end of the age cluster making the findings of these studies not truly representative of the older end of the age cluster.

The research grouped the sample into age categories of 55-59, 60-69, 70-79 and 80-83 and counted how many women were in each group. This number was then calculated as a percentage to illustrate the different proportions of ages within the sample set as illustrated in *Figure 4-37* below.

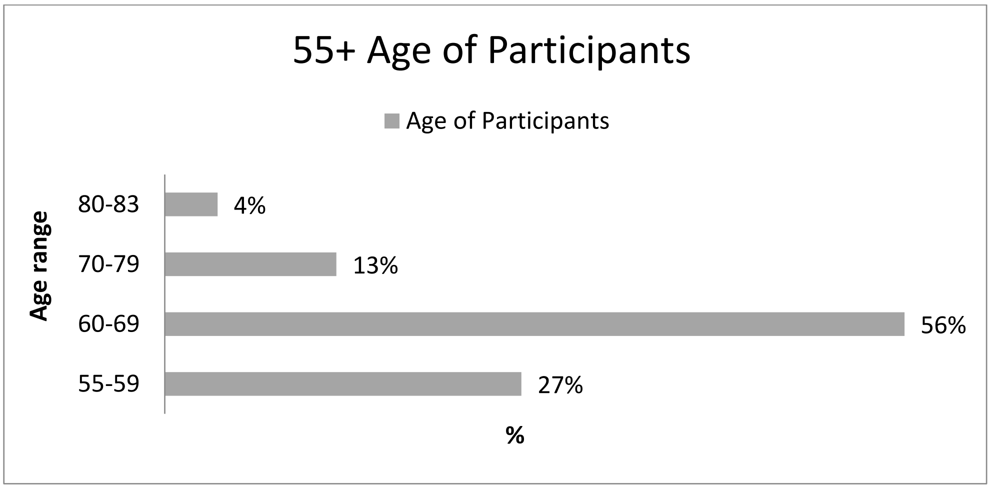


Figure 4-37 Most common age 55+ sample

The found that the 55+ sample ages ranged from 55-83 with 56% of the sample consisting of women mainly in their 60s (*Figure 4-37*). This finding indicated that the 'younger end' of the 55+ sample was more likely to participate with the anthropometric survey which aligns with that of previous research discussed in section 2.5 of the literature review chapter.

As discussed in section 3.12.7 of the methodology chapter each scan file was opened (for the entire sample of ages 18-55+) as a point cloud and had their measurements extracted using the 03_4cm_tolerence MEP file. Both the scan image and list of measurements were viewed for posture had the measurements for BMI and body shape recorded and calculated within an Excel spreadsheet. In addition observations were also documented within this Excel sheet (see Appendix R for context).

Calculating body shape was important as it was found early on in this research the body scanner was placing the waist measurement at the under bust on that women who displayed a large abdomen or appeared to have a less visually discernable waist as illustrated by *Figure 4-9* nearer the beginning of this chapter. This area of the body had already been confirmed as difficult to landmark using non-contact anthropometric methods (Gill *et al,* 2014a). Therefore this research wanted to be explore if body shape, particularly a rectangular body shape, was a variable when combined with age which impacted on landmarking accuracy and as older women are more prone to displaying a rectangle shape (Goldsberry *et al* 1996).

Body shape was calculated using Lee *et al's* (2007) method of calculation (as in Appendix S) using the modified scans for bust, waist, high hip and low hip measurements from the 03_4cm_tolerence MEP file which had previously been batch processed see *Figure 3-11*. It was important to use the modified scans as these had been validated through the SLVM process. Each body shape was defined using the definitions of nine body shapes from the female figure identification technique developed by both Simmons (2002) and Davarajan and Istook (2004) see Table 3-10.

This research found the most common body shape for the 55+ female sample was the rectangle (*Figure 4-38*) at 83% (Appendix AD for full research paper). The average age of the menopause is 52 (Ley *et al,* 1992) so women in their 60s would already have experienced body shape change that arose as a result of the menopausal transition and this research found that currently the rectangle body shape is the shape most likely to occur in women aged 55+ years. This concurred with Goldsberry *at al's* (1996) earlier research (2.5.1), which indicated that the rectangle has been the predominant body shape for women aged 55+ for the past 18 years. What made this finding different from Goldsberry *et al's* (1996) work was that this research provided background on age-related body shape change and, as such, facilitated a greater understanding of why the rectangle shape is so dominant for this demographic. This was not discussed in the work of Goldsberry *et al* (1996).

Hourglass, bottom hourglass and triangle were represented in the 55+ sample to a much lesser extent (Wren *et al,* 2014). This indicated the survey did successfully capture a variety of body shapes for this demographic, given that the sample size was relatively small and the rectangle is so dominant. Body shapes that were missing from the sample were top hourglass and inverted triangle both of which can indicate a larger bust and smaller hip (Table 3-10). This finding is interesting as some of the sample indicated issues with garments fitting the bust waist and hips (*Figure 4-23*). Both bottom hourglass and triangle were represented in the sample which indicated that a small proportion of the women had larger circumference values around the lower region of their torso when compare to their upper torso. The triangle definition also stated that the waist is less visually discernible and so, when coupled with the percentage of those who displayed a rectangle shape, indicated that the majority (91%) of the sample's body shape did not have a visually discernible waist shape. This indicated the issues regarding waist position in each scan, confirmed that body shape was a possible variable (larger samples would further validate this) when combined with age which has the potential to introduce waist position landmarking error when using non-contact anthropometric approaches. It also made the use of the visual aid more vital for the 55+ female demographic.

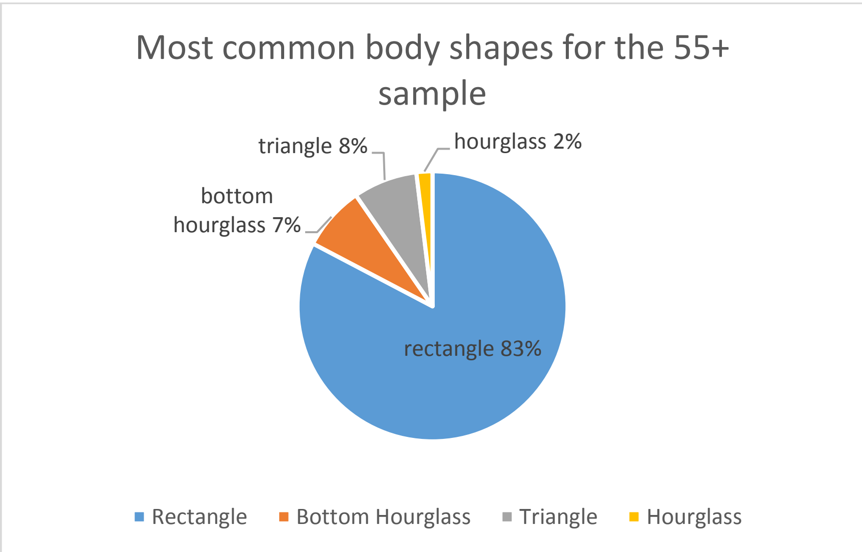


Figure 4-38 Most common body shape for the aged 55+ sample source: (Wren et al, 2014)

This research then calculated BMI scores using the same measurements supplied by the 03_4cm_tolerence MEP file for the 55+ female demographic. The research used the process outlined in Table 3-8, and the calculation illustrated in *Table 3-9.*

BMI scores for the 55+ female demographic revealed that the majority of the sample were either rated as obese or overweight (*Figure 4-39*). This was the only age cluster which had BMI scores within the 'very obese' category. A mature female demographic is prone to height loss due to postural change as part of the ageing process (2.3.1) and as BMI requires height as part of its scoring calculation (3.12.8) this research recognised that the loss of height may make the sample more prone to achieving higher BMI scores (Table 3-8).

High BMI scores could indicate a body type that is either muscular or corpulent but it had already been established that as a person aged their body is prone to carrying more adipose fat (Ley *et al,* 1992). Therefore, it could be deduced that the 55+ age cluster would be carrying more body fat than muscle and thereby be classified as corpulent. It had already been established that scanning corpulent participants could result in scans with occlusions (Ashdown & Na, 2008), which could impact on landmarking and measurement reading accuracy as a result of data-loss (van Stralen *et al*, 2003). Previous research indicated that this demographic gained weight around the torso region of the body, where the waist area could be less distinct (Ley *et al,* 2007). This would explain the rectangular shaping to the torso, the recorded issues regarding the fit of the waist on garments (*Figure 4-23*), and the preference for wearing the waistband/line in a particular position on the body (*Figure 4-27*; *Figure 4-26*).

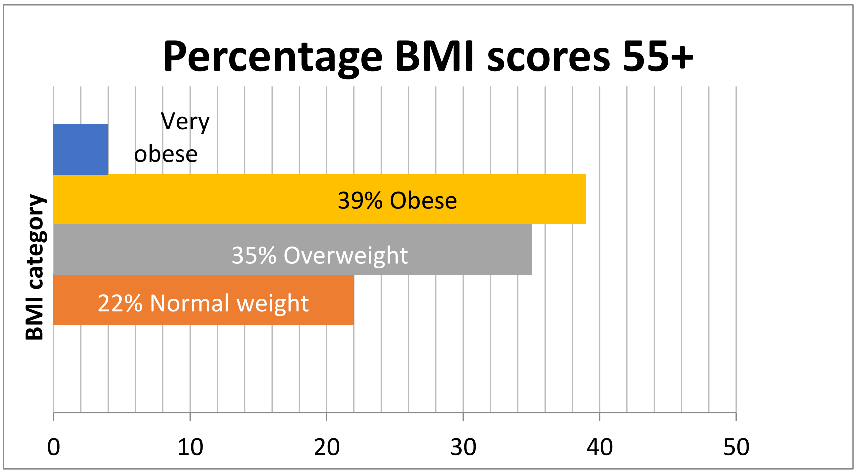


Figure 4-39 BMI categories for the 55+ age cluster

The CDVELA dictated that the same processes and calculations were used for the two younger age clusters (18-25 and 35-45 year olds) as an aspect of the CDVELA is to compare age clusters. The proportions of age within each sample set, body shape and BMI were determined and are illustrated and discussed below.

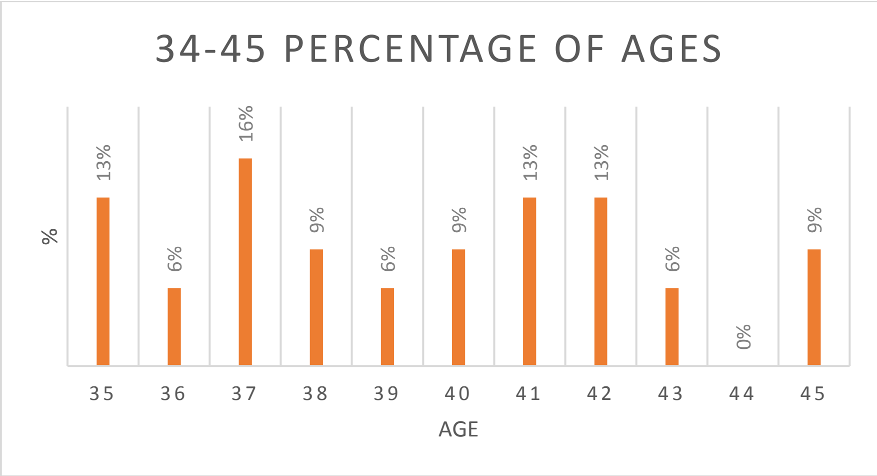


Figure 4-40 percentages of ages within the 35-45 age cluster

As the age range for 35-45 cluster was eleven years, the spread was narrower than that of the 55+ sample. Each age was represented within the sample apart from age 44 (*Figure 4-41*). Age 37 was the most frequent (16% of the sample). This research acknowledges the sample was small, only 32 women, and this presented a limitation. It also confirmed that this age cluster would benefit from being comparable in size to the other two age clusters and that each age should be present in the sample set. Nevertheless, the size of sample was what was available at the time and when added to the other age clusters was greater than any other comparable research using 3D bodyscanning technology (Table 3-4).

The most common body shape for the 35-45 sample was the rectangle (*Figure 4-41)* at 66%. This was a significant proportion of the sample and highlighted that the waist definition for this sample was less visually distinct (Table 3-10). Added to this, some of the age cluster displayed a triangle shape, which had also defined as having a less discernible waist shape (Table 3-10). This meant that 72% of this age cluster had a body shape, which displayed an indistinct waist shape, which in turn indicated that there could be problems concerning correct waist positioning within the scans.

Women in this demographic typically had not entered menopause (Ley *et al*, 1992) but they were of an age where lifestyle choices, environment and health could impact on body shape. Bottom hourglass was the second most identified shape at 16% (*Figure 4-41*). The top hourglass, triangle and hourglass were represented but with much smaller percentages - all 6% each – which indicated that these shapes were more scarce within this demographic.

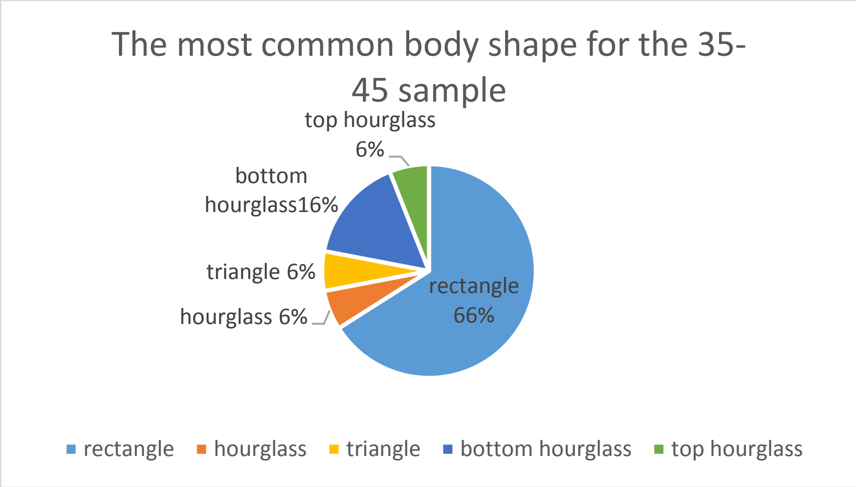


Figure 4-41 Most common body shape for the 35-45 sample

It is noteworthy that a proportion of the 35-45 age cluster were categorised as a rectangle body shape. This is because women from this age bracket have generally have not entered menopause but they are of an age where lifestyle choices, environment and health may impact on their body shape. Bottom hourglass was the second largest identified shape (16%). The top hourglass, triangle and hourglass were represented in much smaller percentages (all 6%) indicating these shapes are scarce but still evident for this in this demographic even in a small sample.

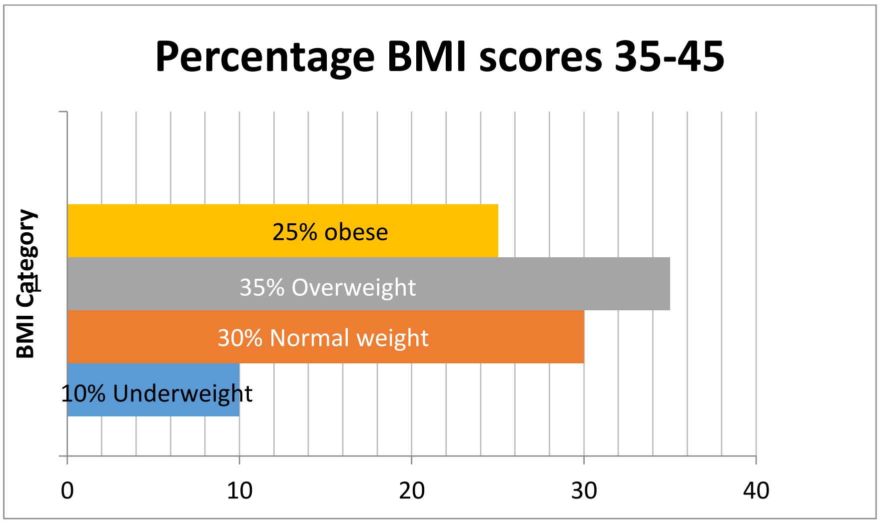


Figure 4-42 BMI categories for the 35-45 age cluster

Thirty-five percent of the 35-45 age cluster fell into the overweight category closely followed by 30% who were normal weight. Twenty-five percent were classed as obese and only 10% as underweight. These findings demonstrated a trend towards overweight/obesity ratings as they formed 60% of the sample – a noteworthy amount.

It was determined that although this cluster's most frequent age (37) is approximately 23 years younger than the most common age group (60s) of the 55+ demographic they, remarkably, share similar body shape and their BMI ratings lean more toward the higher rating of overweight or obese. This research used these variables to establish if scanner accuracy was the same for both age clusters. This will be discussed in the next section.

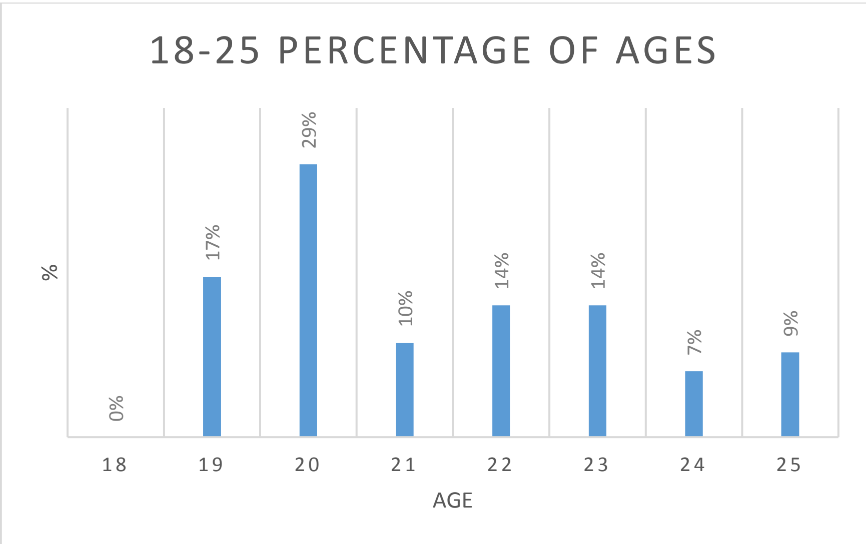


Figure 4-43 Percentages of each age in the 18-25 age cluster

The 18-25 year old age cluster also had a narrower age range than that of the 55+ sample (*Figure 4-43*). Twenty-nine percent of the cluster were aged 20, which was the largest group. However, there were more participants aged over 20 than those under.

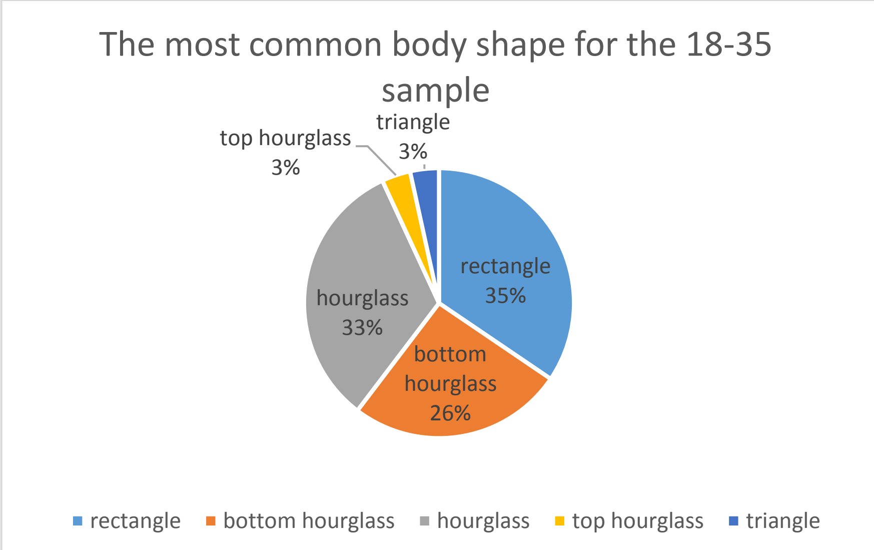


Figure 4-44 Most common body shape for the 18-25 age cluster

The spread of body shapes was also interesting as demographic largely fitted into 3 shapes: rectangle (35%), hourglass (33%) and bottom hourglass (26%) (*Figure 4-44*). Top hourglass and triangle were represented but the percentages were very small at 3% each. No participants from this age cluster displayed an inverted triangle body shape.

The results of these findings indicated that the 18-25 age cluster generally displayed a discernible waist shape, which concurred with the research of Wells *et al,* (2007), that stated that younger women were more likely to have indentations around the torso to indicate waist positioning. This research deduced that these scans would exhibit greater waist landmarking accuracy as the skin surface terrain provided explicit topographical details of where the waist would lie.

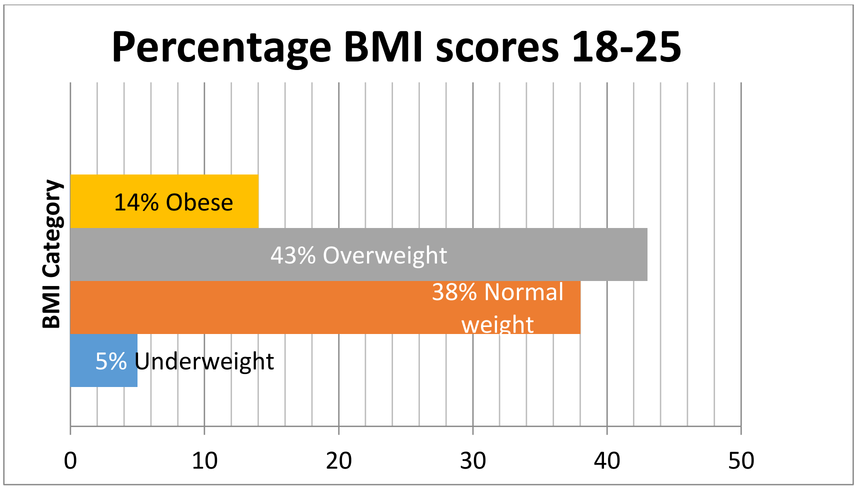


Figure 4-45 BMI categories for the 18-35 age cluster

The largest percentage of BMI scores for the 18-25 age cluster was the overweight category at 43% although scores were mixed for this age cluster overall. Thirty-eight percent scored a normal weight BMI rating (*Figure 4-45*). Interestingly, 14% of this age cluster were categorised as obese but, as stated previously, a higher BMI can be due to either higher muscle or fat mass. As this was the youngest demographic, muscle mass was could also have contributed to BMI. Conversely, this research calculated that when the percentages of normal (38%) BMI and underweight (5%) BMI were combined, 43% of the sample displayed lower BMI and, hence, were carrying less fat and/or muscle. Based on the results thus far, this research deduced that this age cluster would have less landmarking errors and miss-scans compared to the 35-45 and 55+ age clusters.

4.7.2 Results of visual examination of landmarking errors for the armpit and shoulder points using the variables of age, body shape and BMI

The CDVELA process allowed comparison of each demographics scan (both through observation analysis and analysis of the quantitative data) to determine whether the variables of body shape, BMI or posture when combined with age were contributing factors to landmarking inaccuracy (3.12.6). The CDVELA process facilitated comparison and discussion of the landmarking errors that were discovered within each age cluster as a part of the SLVM process.

This research found by reviewing the SLVM documentation (Appendix P) and counting all the landmarking errors identified within the SLVM process, that the most frequent landmarking errors for all age clusters occurred on the front and back armpit and shoulder points (*Figure 4-35*). This had also been confirmed by the t-test (4.6.2) showing that this region of the body is problematic for non-contact anthropometric approaches. These are important landmarks for pattern making as, according to pattern construction guidance (listed in Appendix C), when combined, they provide body measurements (with added ease values) for the development of the armscye/armhole and sleeve. Therefore, this research surmised at this point that any landmarking error within this region of the body impacts negatively on the garment fit. Of course this would be later confirmed when the unmodified and modified scan measurements were tested using pattern and garment development.

The 55+ sample had already stated that they had experienced poor fit in armscye/armhole and sleeve area of the garment (Appendix AE: 746; Appendix AE: 748). Therefore this research had used the combined armscye circumference measurement within the TC² bodyscanner software (the measurement is coded as W18, see Appendix U) to establish accuracy in landmark placement. *Figure 4-46* shows a correct armscye girth measurement in that the front and back armpit points lie directly on the crease of the armpit and the shoulder point is positioned at the point of tangential change (the point of angle change from shoulder and down the arm). The TC² body scanner has two means to determine the shoulder point (*Figure 4-47*), one relates to the underarm points as a constant angle which meets the virtual skin surface and one determined as an angular change from the shoulder to upper arms. Whilst the settings may be modified by a technician, differences in participant scan posture, body morphology and landmark placement will all result in a need to manually check and correct shoulder points via the SLVM process to sit in a position equitable to the shoulder as defined through traditional measurement methods (Gill, 2017,Appendix AJ).

The results of the hypothesis confirmed the null hypothesis as true, that the independent variable of age does not affect the landmarking accuracy of this region. However as stated in 4.4.7 and 4.6.2 armhole fit as reoccurring issue for mature women, the SLVM process revealed that landmarking error for both armhole depth and width occurred within all the age clusters and indeed was the portion of the body which showed the highest frequency of landmarking error as presented in *Figure 4-35*.

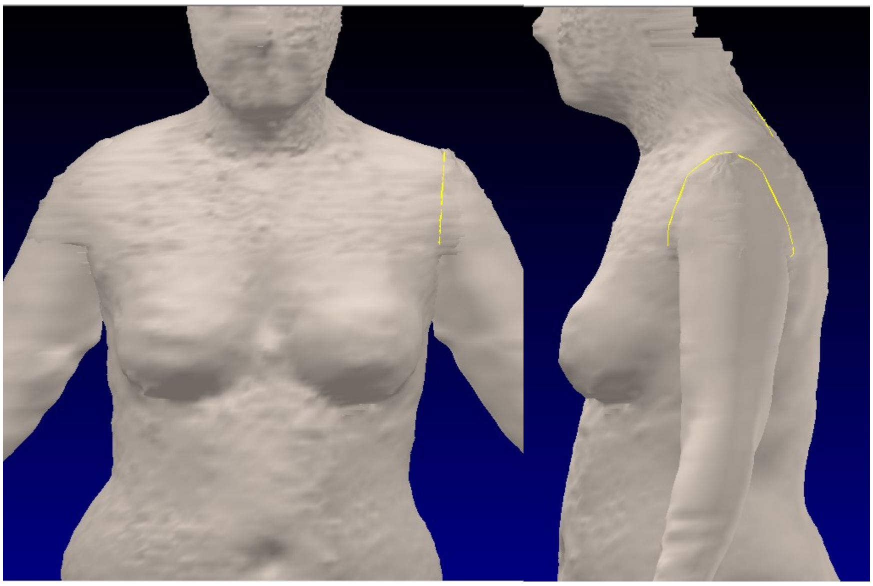
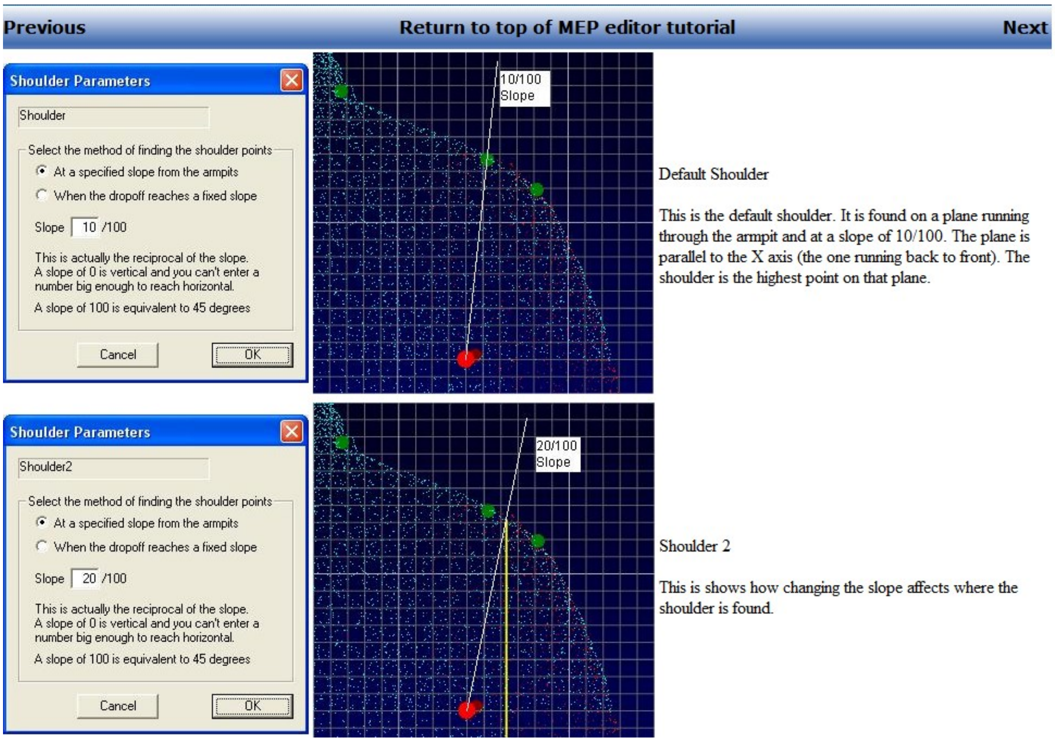


Figure 4-46 A correct armscye girth (W18) measurement



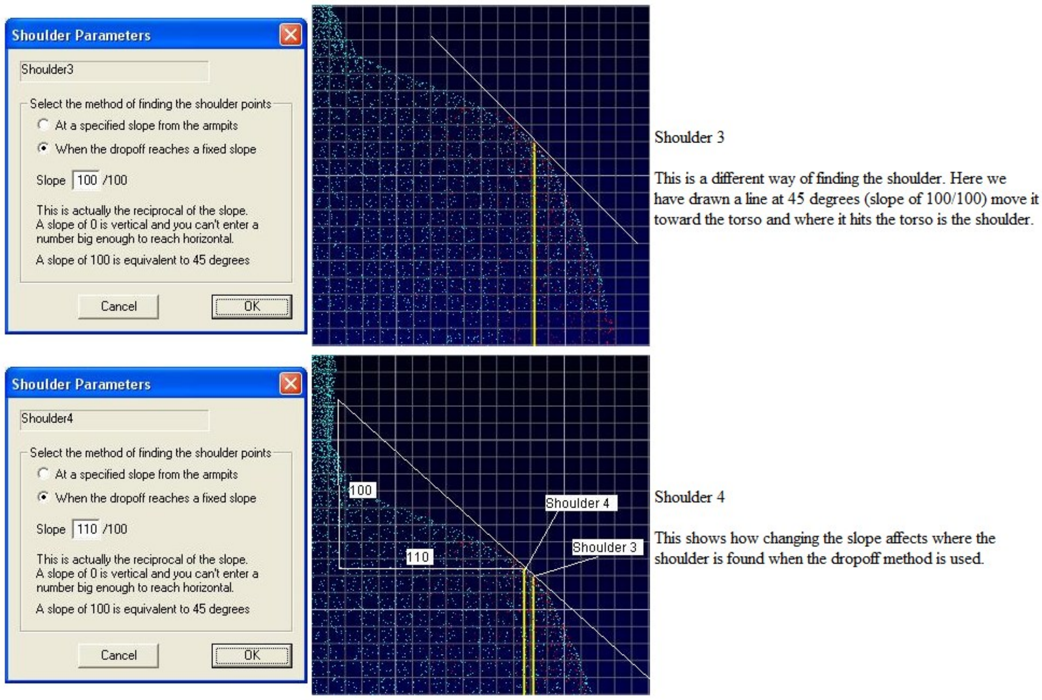


Figure 4-47 TC² shoulder parameters found within the MEP editor Source: Gill (2017)

The 55+ age cluster, had the highest occurrence of armscye error - 35 observations - double that of the 35-45 cluster and over a third more than the 18-25 cluster (*Figure 4-35*).

However, the 18-25 age cluster had the next largest occurrence with 21 observations of this error appearing as illustrated in *Figure 4-35*. It should be noted that the 18-25 age cluster had the largest sample (66 participants) and their body shape categories were mixed (*Figure 4-44*) with their BMI scores more inclined toward being overweight or obese (*Figure 4-45*). Therefore, with these variables in mind, it was reasonable to expect more landmarking errors to occur.

The 35-45 age cluster had the smallest frequency of armpit/shoulder landmarking errors, only 13 observations. This was interesting as this age cluster shared similar body shapes (*Figure 4-41*) and BMI categorisations (*Figure 4-42*) to the 55+ sample. However, as this demographic had a smaller sample size a lower occurrence of this landmarking error could have been predicted.

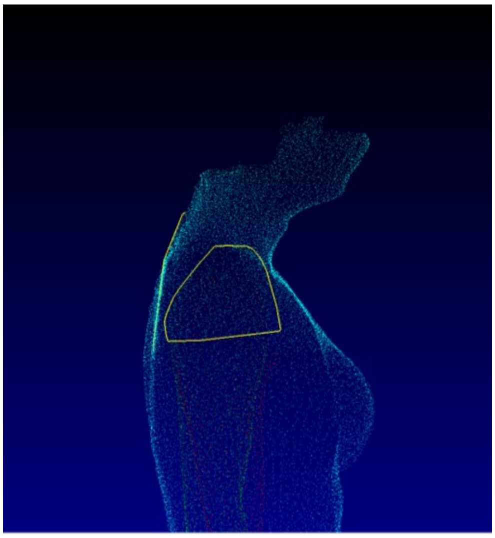


Figure 4-48 Participant aged 20 - TC²'s armscye girth (W18) measurement

Shimokata *et al's* (1989) work confirmed that the mature women's arm circumference and fat distribution around the triceps and subscapular could increase in women from the ages of 40-70 (2.2.3). This could explain this landmarking error in both the 55+ and 35-45 year old clusters.

Lee and Nah's (2008) work stated that older women's body morphology (those over 55 years) could display a larger bust with an increased bust circumference (2.2.3). This research found that adipose fat deposits on the shoulder blades and triceps as well as a large bust can contribute to landmarking error in this region of the body. Ashdown and Na (2008) also stated that older women could manifest bilateral asymmetry of the body with the left and right sides of the body not displaying symmetry. All of these morphological changes can and do impact on landmarking accuracy for the 55+ age cluster.

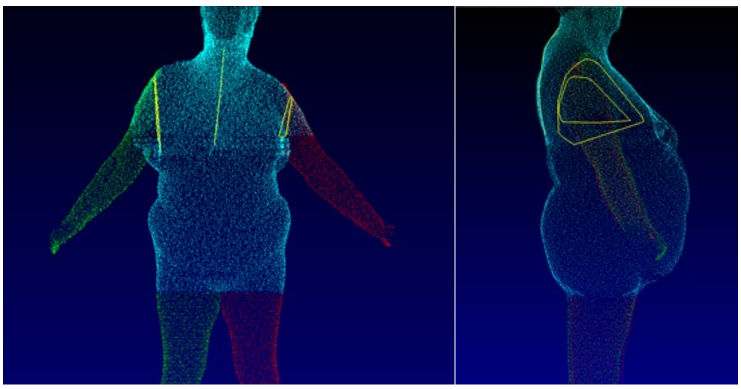


Figure 4-49 Participant aged 73 - Landmarking errors of the front, back and shoulder points

Figure 4-49 was a participant from the 55+ age cluster whose body morphology manifested the changes discussed directly above. Her body shape was categorised as a rectangle and her BMI score placed her in the obese category, which were the two most common categories (*Figure 4-49*). The participant's body showed a level of bilateral asymmetry around the shoulders. The shoulder points were not placed correctly as right and left shoulders were not placed on the point of angle change (*Figure 4-49*).

Sims *et al's* (2011) work found that the TC^2 bodyscanner relied on the use of a body model template in its software to enable the scanned image to be more accurately interpolated into a point cloud shape. Their work determined that individuals whose body morphology did not match the predetermined template could not be provided with complete body measurements (2.2.1). Interestingly, their work involved individuals who had health or mobility issues and their work set evaluated the accuracy of scanning for this sector of the population. This research concluded that, as this participant's shoulder posture had moved away from what is considered standard. The scanner was unable to align the shoulders of the participant to that of the body model template thereby resulting in errors in shoulder point placement which was determined earlier in on in the research and discussed in section 4.5.2 and illustrated in *Figure 4-33*.

The 55+ sample recruited by this research were mobile and able bodied. Therefore, it is noteworthy that this error occurred as a result of body template issues. Consequently, this research found that the SLVM and CDVELA processes needed to be undertaken first to ensure those with non-standard body morphologies had their landmarks corrected to ensure their inclusion and secondly because of the parameters used within the software to determine landmark placement for the armscye.

It is important to note here that despite this research's interest in landmarking accuracy for a mature female demographic. It found that landmarking error for this body region consistently occurred across all ages, body shapes and BMIs indicating that non-contact landmarking of this region of the body is unreliable which is a new finding and one that contributes to the knowledge base concerning non-contact anthropometric practice.

To quantify the amount of landmarking errors for this body region this research took the same approach it had done for the waist landmark (*Figure 4-36*) and subtracted the modified armscye girth measurement from the original armscye girth measurement to give a value difference score for the armscye girth. This calculation was undertaken to determine how much the armscye girth had increased/decreased in girth as large numerical changes would impact on garment fit. The values contained both negative and positive numbers but *Figure 4-50* shows there was a trend towards positive numbers.

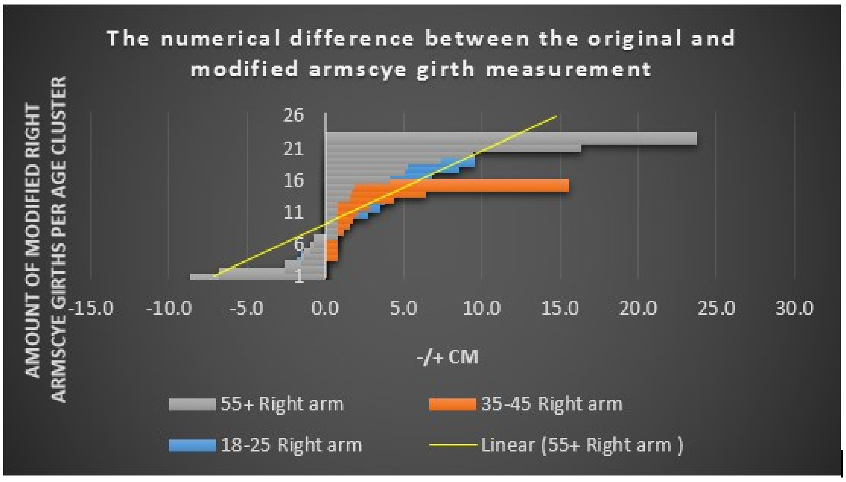


Figure 4-50 Value difference when original and modified armscye girth measurements are extracted for the right arm - all age clusters

This research also wanted to establish whether any of the age clusters showed a trend of high positive or negative values that indicated the depth of error. *Figure 4-50* showed that the 55+ age cluster manifested the highest positive and negative values as the longest grey data point line either side of the 0.0 cm line showed values of plus 23.7cm and minus 8.6cm. This indicated that for some of the 55+ cluster the placement of the front and back armpits and the shoulder point on the original scan were substantially different (numerically speaking) from where the landmarks actually should be according to the definition within the scanner database.

Producing a chart to show the value difference in measurements is informative for a clothing practitioner as the erroneous measurement will impact clothing fit and clothing fit is important for greater customer satisfaction and increased sales. Therefore, to appreciate the impact of incorrect armscye measurement on garment fit, this research used both original and modified scan data to develop a bodice pattern. This will be discussed further on in this chapter.

4.7.3 Landmarking errors of the crotch point

From a clothing perspective, the crotch point is an important landmark as it is a body measurement which, when combined with other landmarks on the torso or the legs, is used as a reference point for garment depth/length measurements or to inform the construction of the front and back rise of a bifurcated garment.

Although this research did not develop a garment which would fit on or around the crotch point because the literature sources indicated that the torso was the part of the body, which manifested the greatest age-related body morphology change as, discussed in section 2.3. The research however felt it prudent to note that the crotch point was the second most reoccurring landmark error for all the age clusters. As with the armpit, the crotch point is a junction of the body. Therefore, it was observed that it is prone similar issues to those mentioned above for the armpit region, and were impacted by phenomena such as excess fat folds which obscured the contours of the crotch, where the limbs touched each other or the torso and showed no discernible gap, where lingerie compressed the skin, and in the case of the crotch point where the feet were placed too close together (4.7.2).

The 18-25 age cluster manifested the largest amount of crotch miss-location error with 16 observations of this occurring (*Figure 4-35*). The 55+ age cluster had 12 observations of crotch miss-location while the 35-45 age cluster had 10 observations (*Figure 4-35*). When compared to the size of each age cluster sample, the number of instances indicated that this error did not show a strong pattern of occurrence for any one of the age clusters. The t-test confirmed that this type of landmark error is more probable due to increased age (section 4.6, *Table 4-25*). With this in mind the research decided to use the CDVELA process to identify whether any particular body type was prone to this error.

Schofield *et al's* (2006) research into pant fit for a mature demographic found that the older female body morphology could display a flatter and wider buttock area and slimmer thighs, which conversely implied that a younger demographic could have the opposite shaping in these body regions. As also discussed in sections 2.3.3 and 4.6 Chumlea *et al* (1980) also found that older women display more subcutaneous fat around the torso region and less so on the limbs. Which these pieces of research in mind this research found that the 18-25 age cluster manifested a higher, rounder buttock region and fuller thigh shape when compared to both the 35-45 and 55+ age clusters, thereby confirming the work of Schofield *et al* (2006). Furthermore, some of the 55+ age cluster's seat and thighs did exhibit some of the age related changes discussed in Schofield *et al's* (2006) work. However, the research found that many of the older demographic also displayed fuller thighs, which like some of the younger demographic (see *Figure 4-51*) touched as illustrated in Figure *4-32*. So for landmarking error of the crotch point it was found that buttocks shaping did not impact on crotch point accuracy but that thigh fullness and lingerie did (*Figure 4-51*).

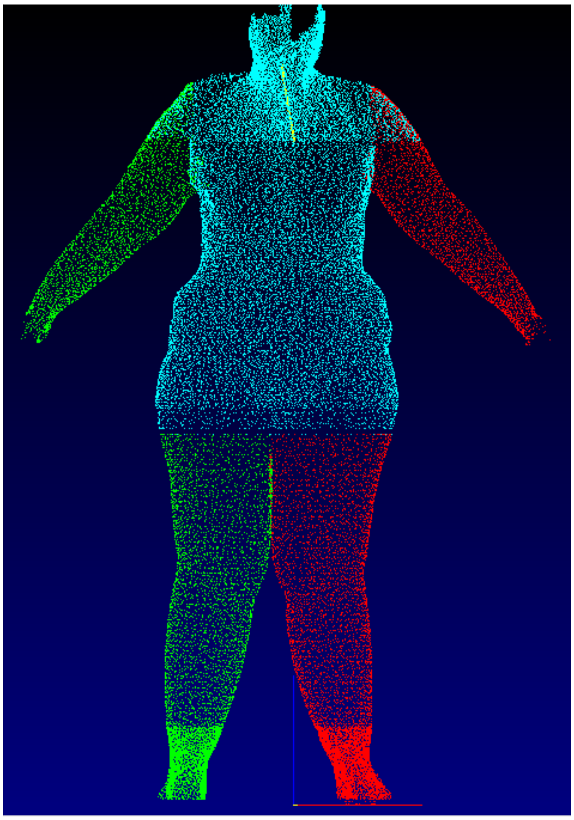


Figure 4-51 Participant age 20 whose thighs touch and whose crotch point landmark is erroneous (scanned using the NX16)

It was also found that crotch point miss-location occurred in both scanner models. Scans captured by the NX16 generally showed the crotch point as either being higher or lower, cutting into the torso region of the body (*Figure 4-52*) or showing the legs as being short and out of proportion for the participants height. Scans captured by the KX16 had occlusions around the crotch and thigh where one thigh's girth looked bigger than the other (*Figure 4-53*).

As discussed previously (2.7.1) the scanner sensors and software capture different facets of the body (Lovato *et al,* 2009) and the resultant point cloud image is colour coded into body sections such as left/right leg/arm and torso (*Figure 3-14*). If the overlapping edges of each sensor view are not patched smoothly (*Figure 4-54*) or shadows are cast by the surrounding body area and picked up by one sensor and not another, then error to the landmark point is possible. Therefore, as the legs are both a junction on the body and seen as a body section (which required patching) by the software it was determined by this research that the answers to this issue could reside in the following areas:

- The level of resolution and positioning of each sensor (both the camera and the light source)
- The software coding used to patch individual image views
- The accuracy of the initial image calibration.

All of these potential areas for investigation to resolve this issue are beyond the skill set of the traditional clothing practitioner.

This research found that by modifying the crotch point landmark using the modify point function (*Figure 3-9*) the software performed a series of interpolations (a means of approximating or estimating an unknown value or function Oxford, 2004; Downing et al, 2003). For example when the crotch point was dragged either up or down the software filled in/opened up a gap between the thighs with extra point cloud coordinates or on a grey surface image voxels (3D pixels).

Crotch point miss-location has been previously identified and discussed in the work of Apeagyei (2010) and Gill (2015). However, where this research builds from Apeagyei (2010) and Gill's (2015) work is that it has further investigated the variables that can contribute to both crotch point and armpit/shoulder miss-location using pre-determined age clusters, something which had not been documented in the literature and is therefore new.

Figure 4-52 Crotch point is placed too high into the torso (scanned using the NX16)

Figure 4-53 missing data around the crotch and upper thigh region (scanned using KX16 scanner)

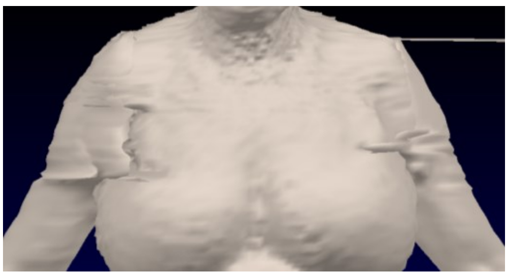


Figure 4-54 Armpit region which is not smoothly patched

In summary, the SLVM processes indicated that there were many landmark errors which were not limited to the 55+ age cluster. This finding indicated that landmark evaluation is essential to ensure the ensuing measurements were accurate, which consequently gave the SLVM and the CDVELA processes greater relevance.

The CDVELA revealed that errors around the armscye and crotch point occurred in participants who had a high BMI score and whose body shape had moved away from the standard body morphology.

The CDVELA also demonstrated that women within the 55+ age cluster were more likely to experience larger armscye circumferences that extended over the breast area. This is shown by the yellow trend line in *Figure 4-50*.

The CDVELA further demonstrated that standard body template used with the TC² scanner software was not appropriate for women with altered posture.

Finally, the CDVELA demonstrated that women through all the age clusters were more likely to experience crotch point miss-location if they displayed a fuller thigh shape.

4.7.4 Participant selected waist location – original waist and modified waist positions (Activities 14 and 18)

Turning now to the self-selected waist location for the 55+ age cluster, which formed the final portion of the CDVELA process and which is an important and novel portion of this research.

The participant's responses to the visual aid were actioned by opening their modified scan file and moving the centre back waist landmark to the position indicated as correct by the participant. This entailed rotating the scan image to a side on profile to correlate with the visual aid images and moving the landmark in the y direction either upwards or down. As discussed in section 3.12.12 of the methodology chapter. Once this was done for each scan the total amount of the scans with waist landmark modification were counted and a percentage calculated to illustrate the proportion of women who required waist landmark's to be modified.

Sixty percent of the 55+ sample required the waist height landmark to be modified to correspond with their chosen visual within the questionnaire (Wren *et al,* 2014, Appendix

AD). This research found that even though a number of subjects had selected visual B – waist = 4cm above the small of the back (*Figure 3-5*) - the landmark had to be manually adjusted to match the proportions on the visual. This is noteworthy the MMU 03_4cm_tolerance MEP already uses this definition (which is directly comparable to that of the SizeUK definition) and therefore it is reasonable to expect that this waist landmark would not need moving as it was already place 4cm up from the participants small of the back. However, the waist landmark did require moving as the waist position had been placed too high (under the bust) and so to match the visual aid proportions it needed moving. This did make the process much more complex and meant that the scanner technician had to rely on their own visual judgment when moving the landmark point. Therefore, this research acknowledged that the more skilled the scanner technician the more accurate the process will be, something which is already recognised within manual anthropometric practice. This research found through experiential use of the scanner that the accuracy of the measurement provided by the scanner is directly affected by the skill-set of the technician using it something which has not been explicitly stated so far in any comparable research.

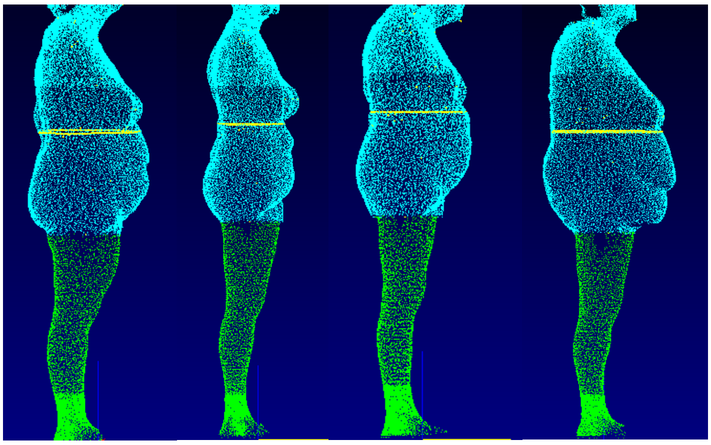


Figure 4-55 Waist positing lying on the under-bust measurement prior to CB waist landmark modification

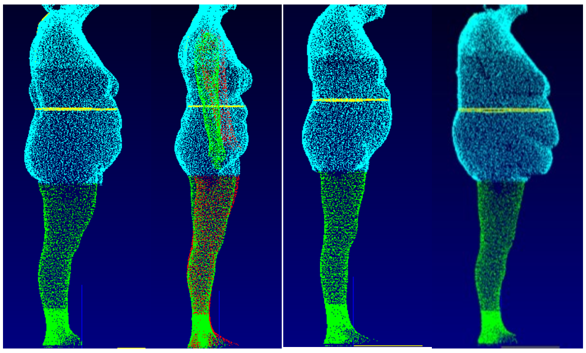


Figure 4-56 Waist positioning after modification of the back waist landmark as selected by the participant

4.7.5 Body shape and landmark modification

The research explored a correlation between body shape and waist landmark modification. It did so by cross checking each participant who required a waist landmark modification against his or her assigned body shape category. Next, the research subtracted the modified waist height from that of the unmodified waist height for each participants scan to give a waist height difference or WHD, details of which have been detailed in section 3.12.13 of the methodology chapter. This calculation provided a value for the distance the landmark had moved a change which directly impacts on the waist girth measurement making it either larger or smaller. Using the WHD again waist the benchmark definition of 4cm upward from the small of the back demonstrated how appropriate or erroneous this benchmark measurement was for each participant. The results of the catagorisation and WHD calculations are presented below in *Figure 4-57*.

Figure 4-57 illustrates each participant's body shape in the X-axis and the WHD in the Y-axis. As illustrated previously, the rectangle shape was the most dominant shape within the 55+ age cluster (*Figure 4-38*) and when the WHD was calculated and cross-checked against the participant's body shape it became apparent that the rectangle shape had the greatest movement change in terms of waist height after modification of the waist landmark. In addition three participants who were rectangle shapes had chosen visuals that resulted in large differences of waist height measurement between minus 10.57 cm and plus 23.67 cm. This occurred because the MMU MEP placed the waist at a significantly different position to the visual they chose which indicated that the waistband position would be visually undesirable and possibly uncomfortable for them. These 3 women either chose visual A, where the waist definition was placed high near the under bust and their small of the back was shallow and low on their body. Alternatively, they chose visual D, which was on the top of the iliac crest (see *Figure 3-5* for context) and the MMU 03_4cm_tolerance MEP had placed their waist at the under bust. This meant the waist height landmark needed to be moved significantly if it were to match the visual they had chosen.

4.7.6 <u>Coefficient variance of WHD (all body shapes)</u>

The research also wanted to determine the ratio of standard deviation to the mean of WHD. To do this the research had to calculate the coefficient variance as this calculation would shows the spread of dispersion around the mean score (statisticshowto, 2017). The calculation for this is expressed below in *Table 4-27.*

$$\boxed{CV = (SD/\overline{X}) * 100}$$

Table 4-27 The calculation for coefficient of variance Source: Statisticshowto (2017)

This calculation divides the standard deviation by the mean score and then multiplies the value by 100 to express the standard deviation as a percentage of the mean (statisticshowto, 2017). The mean score of all the WHD was calculated as 1.14 and the standard deviation 5.97. The coefficient variance was found to be 24% of the mean.

4.7.7 <u>Waist landmark modification summary</u>

The pale grey line running through the middle of *Figure* 4-57 represented the MMU 03_4cm_tolerance waist landmark which is defined as:

> B. Using the spinal curves and placed above the small of the back
> with a 4cm tolerance (Table 3-5)

The modifications of the waist moved either side of this line as shown in *Figure 4-57* below. There 31 observations of landmark modification and these consisted of 19 observations of the waist landmark moving above this line, 6 observations of the landmark remaining on this line and 6 observations of the waist landmark moving below the line. Either side of the line were positive WHD values following an upwards direction and negative WHD values following a downwards direction. This is indicated by a +/ cm measurement at the left side of the chart (*Figure 4-57*). Contrariwise positive WHD values showed that the waist landmark had decreased in height as the WHD is the numerical difference between the original waist to floor height and the modified waist to floor height, and negative WHD values showed that the waist landmark had increased in height. As there were 19 observations in a positive upward direction above the grey line it can be stated that more participants had their waist landmarks lowered. This was because many waist circumferences were placed on or around the under bust region and that was not the position the participant had chosen. This is noteworthy as it indicates that definition B (used by SizeUK) which uses the spinal curves and places the waist landmark above the small of the back with a 4cm tolerance is not appropriate for this demographic.

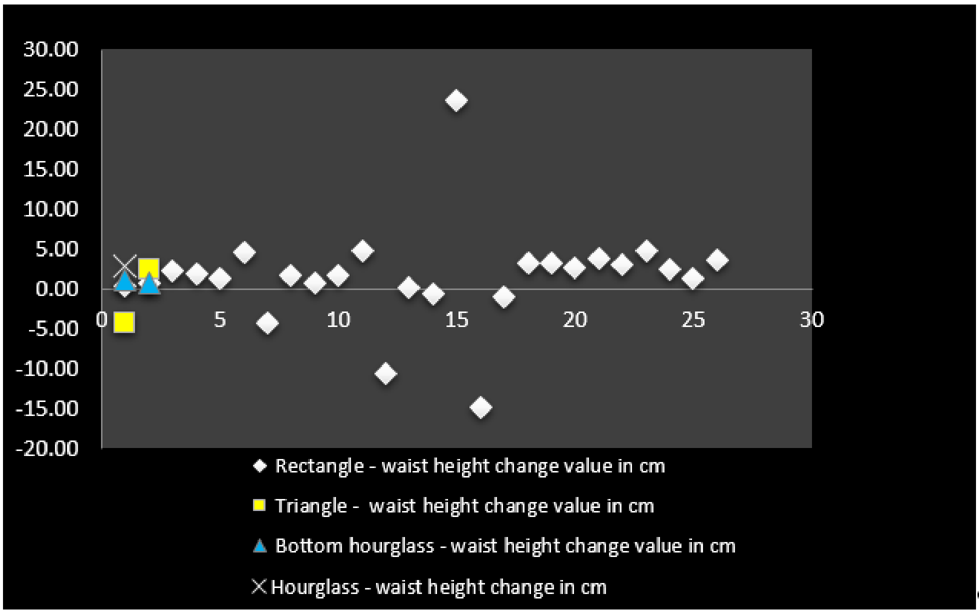


Figure 4-57 the correlation of waist height difference (WHD) and body shape

4.8 Testing and validating the SLVM and CDVELA processes using pattern block development Objective [5] (Activities 27 and 28)

Both the SLVM and the CDVELA needed validation and this research determined that using pattern development would be the best tool to test the viability of both the original and modified scan measurements (*Figure 3-1, Table 3-2*: Activity 27 and 28). This is because accurate body measurements will develop accurate patterns and garments and so any manual amendment to the body measurements after scanning is complete needed to be scrutinised within the context of the pattern and the garment.

The sample had to be reduced for pattern development and toile fitting as the PhD had time constraints and it was not feasible to make patterns for the entire sample which now consisted of 148 women. As discussed in section 3.14 the sample was reduced using the following criteria:

Each group needed to contain a participant from each of the demographics (18-25; 35-45; 55+) to address Objective [3] and Objective [5].	
1	Each person should share a similar height.
2	Each scan should show all valid measurements for a bodice pattern in both the unmodified and modified versions.
3	Each participant's scan needed to have two or more landmark modifications, as this would demonstrate the scanner had some difficulties in placing landmarks accurately at some stage.
4	Consent, availability and proximity for toile fitting for the 3 women from the 55+ sample only.

This meant that nine women were chosen two women from each of the age clusters. *Figure 4-62, Figure 4-63* and Figure 4-64 show these women within their height groupings front on and in profile and give the viewer a better ideal idea of the participants body shape. The research used both unmodified and modified scan measurements, which meant that 18 patterns were to be drafted, which will be discussed in detail further on in this section.

Beazley and Bond's (2003) pattern construction guidance was chosen for its method as all but one of its measurements use direct and not proportional body measurements. Its method also facilitated depth measurements from the side neck point to the bust prominence and bust prominence to waist. This was determined as very important given that within the questionnaire participants had stated that they had experienced poor fit in the bust region (see *Figure 4-24*), the results of the SLVM indicated issues with bust point placement (*Figure 4-35*) and t-test for the bust girth provided confirmation that landmarking error of the bust is more likely to occur on a women who is aged 55+ (*Table 4-26*).

Beazley and Bond’s (2003) bodice pattern guidance requires 12 body measurements be gathered. Measurements from unmodified and modified scans were collated in an Excel spreadsheet shown below in *Figure 4-58.*

Selected sample of participants for pattern generation

Subject code	subject shape	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	(b) W108 Waist girth original	(b) W108 Waist girth cleaned scan	(c) W87 Neck base girth original	(c) W87 Neck base girth cleaned scan	(d) W12 Back neck depth (back neck rise)original	(d) W12 Back neck depth(back neck rise) cleaned scan	e [40a]-BkNeck-2-WaistLength-(e) original	e [40a]-BkNeck-2-WaistLength- (e) cleaned	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	h [??]-SideNeck2Waist-overbust-(h) original	h [??]-SideNeck2Waist-overbust-(h)cleaned	g [??]-SideNeck2Bust-R-(g) original	g [??]-SideNeck2Bust-R-(g) cleaned
C65	triangle	119.26	119.27	107.25	108.84	42.57	42.57	2.00	2.00	38.13	40.33	21.83	21.83	43.50	44.97	34.21	34.20
I 55	bottom hc	98.59	98.44	75.55	77.88	38.40	38.04	2.00	2.00	35.49	37.06	17.06	17.56	41.23	42.34	29.08	29.29
F 70	rectangle	116.39	116.63	99.16	100.69	42.00	42.00	2.00	2.00	41.90	43.33	22.82	22.82	46.06	47.37	33.52	33.52
H 35	rectangle	101.16	101.16	87.70	88.34	37.61	37.61	2.00	2.00	37.86	39.05	18.55	19.55	41.04	42.15	27.69	27.69
E 43	bottom hc	105.70	105.70	87.72	90.45	43.68	43.68	2.00	2.00	37.28	39.16	15.55	15.55	44.11	45.68	32.04	32.04
B 36	rectangle	88.19	88.19	71.84	71.84	36.54	36.54	2.00	2.00	40.30	40.30	12.97	12.97	41.27	41.27	25.53	25.53
G 23	hourglass	108.22	109.24	86.20	86.20	39.94	39.94	2.00	2.00	40.64	40.64	17.36	17.36	44.07	44.07	26.96	26.96
A 25	bottom hc	96.02	96.57	78.65	80.80	36.37	36.38	2.00	2.00	34.45	36.05	14.97	17.48	41.54	42.42	30.06	30.06
D 23	bottom hc	95.11	95.11	80.77	80.77	37.51	37.51	2.00	2.00	37.76	37.76	16.93	16.93	39.09	39.09	27.36	27.36

each grouping shares a similar height

x front and back measures are not pitched at the same level. Check scanner definitions

samples were selected according to height, amount of modifications and to give an even spread of body shape classifications

height group from 153-153.5
height grouping from 165.1-166.5
height grouping all 165

no young participants in the shorter height groups and no over 55s in the tallest height groups

	e [40a]-BkNeck-2-WaistLength-(e) original	e [40a]-BkNeck-2-WaistLength- (e) cleaned	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	h [??]-SideNeck2Waist-overbust-(h) original	h [??]-SideNeck2Waist-overbust-(h)cleaned	g [??]-SideNeck2Bust-R-(g) original	g [??]-SideNeck2Bust-R-(g) cleaned	l W83 Xback before cleaned	l W83 Xback after cleaning	j W85 X frnt before cleaning	j W85 X frnt after cleaning	k W91 R shoulder length before cleaning	k W91 R shoulder length after cleaning	LW86 bust to bust before cleaning	L W86 bust to bust after cleaning	m W94R width of armhole before cleaning	m W94R width of armhole after cleaning
3	38.13	40.33	21.83	21.83	43.50	44.97	34.21	34.20	37.79	37.79	41.37	41.37	14.84	14.84	26.46	26.46	14.77	14.77
4	35.49	37.06	17.06	17.56	41.23	42.34	29.08	29.29	33.04	32.14	29.24	27.05	10.90	11.60	19.57	19.57	13.32	13.32
5	41.90	43.33	22.82	22.82	46.06	47.37	33.52	33.52	39.40	39.40	39.70	45.06	15.00	15.57	23.61	23.61	13.8 (L)	13.50
6																		
7	37.86	39.05	18.55	19.55	41.04	42.15	27.69	27.69	27.18	32.65	37.48	37.49	11.92	11.92	23.45	23.45	15.41	14.82
8	37.28	39.16	15.55	15.55	44.11	45.68	32.04	32.04	29.59	29.59	42.64	42.64	12.42	16.20	23.99	23.99	17.68	17.68
9	40.30	40.30	12.97	12.97	41.27	41.27	25.53	25.53	32.34	32.34	30.26	30.26	10.57	13.50	17.08	17.08	10.48	10.48
10																		
11	40.64	40.64	17.36	17.36	44.07	44.07	26.96	26.96	33.00	33.00	33.30	40.43	9.25	13.10	23.49	23.49	18.86	15.32
12	34.45	36.05	14.97	17.48	41.54	42.42	30.06	30.06	27.21	32.77	32.02	37.81	7.84	14.90	21.28	21.28	17.53	13.30
13	37.76	37.76	16.93	16.93	39.09	39.09	27.36	27.36	32.11	32.10	37.20	37.20	13.44	13.44	23.12	23.12	12.33	12.33

x front and back measures are not pitched at the same level. Check scanner definitions against Beazley and Bonds

e classifications

Figure 4-58 Excel sheet of the collated modified and unmodified pattern measurements

The patterns were drafted manually - as explained in section 3.15.1 - and were critiqued validated by an academic with 30 years of pattern drafting experience as detailed in section 3.15.2. Their feedback can be viewed in Appendix W. Once the pattern were drafted they were digitised into the Gerber system to preserve them, to add on seam allowance and to enable them to be viewed side by side on screen (*Figure 4-59*). Once this task was completed the patterns were opened into illustrator so their shape could be copied enabling them to be captioned as detailed in the section below (4.8.1). This was done to make it easier for the viewer to determine which age group the pattern represented and if the pattern was developed using unmodified or modified scan measurements.

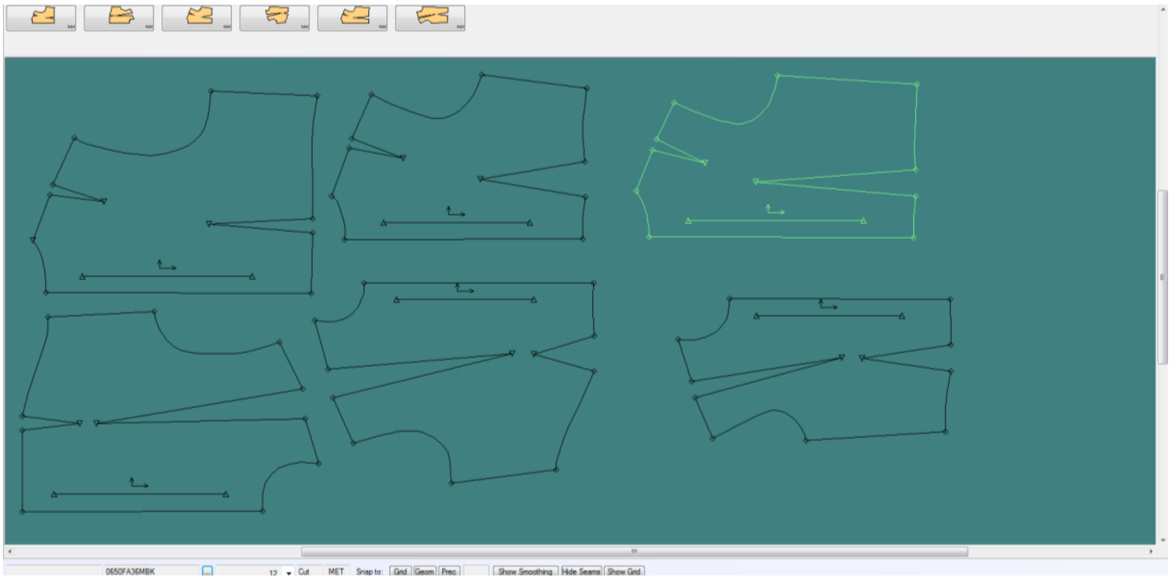


Figure 4-59 Height group 153 - 153.5 digitised patterns (modified)

4.8.1 An explanation of the pattern captions/key

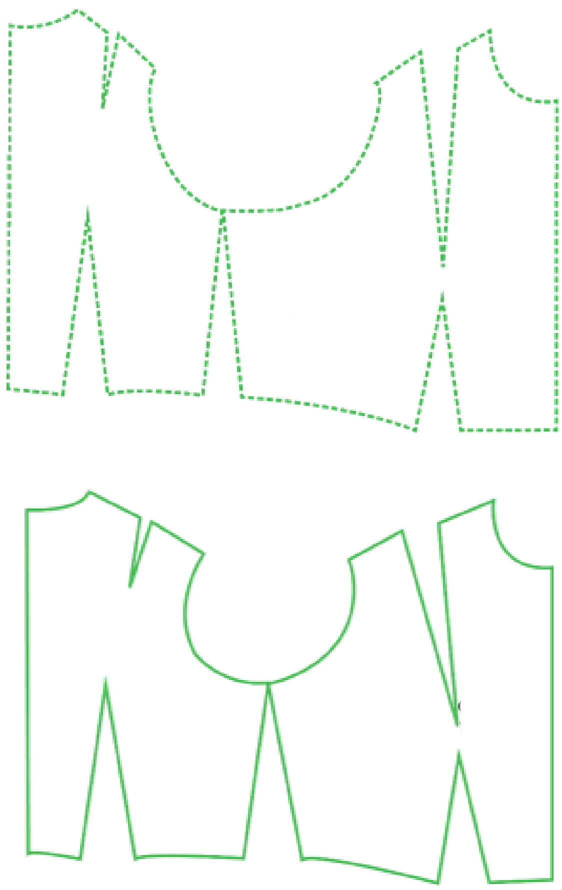
For clarity, it should be noted that all the patterns are illustrated in different colours for each age cluster. The colours used are shown below in *Figure 4-60*. In addition, the research needed to make clear which pattern shapes came from unmodified scan data and which were from modified scan data. It did so using different line attributes. Therefore patterns which used unmodified scan data are illustrated with a dashed/broken line and patterns which used modified scan data have a solid/unbroken line as demonstrated in the key which is *Figure 4-60* below and in images of example patterns in *Figure 4-61.*

All the individual patterns proportions are preserved to show the differences in body size, BMI, and body shape between individuals as well as to clearly show the difference in pattern shape/geometry between unmodified and modified pattern shapes. The pattern pieces are presented in a vertical position (*Figure 4-61*) rather than the horizontal position (as is the default for Gerber *Figure 4-59*) to clearly show armhole shaping, dart lengths and differences in pattern length.

Green = 18-25
Blue = 35-45
Red = 55+

------------ = line used for patterns developed from an unmodified scan data
= line used patterns developed from a modified scan data

Figure 4-60 Caption/key to determine which patterns were drafted from unmodified and modified scan data. This caption/key also uses colours to show what age group the pattern belongs to



The bodice drawn with a green dashed line represents a pattern for a participant from the 18-25 age range that has been developed using unmodified scan data.

The bodice drawn with an unbroken line represented a pattern for a participant from the 18-25 age range using modified scan data.

Figure 4-61 Examples the colour and line attributes of patterns drafted from unmodified and modified scan data

All the patterns proportions were preserved to show the differences in body size, BMI, and body shape as well as to clearly show the difference in pattern shape/geometry between unmodified and modified pattern shapes.

4.8.2 Scan images of the nine participants selected for pattern development

Below are the scan images of the participants selected for pattern development. There are three height groups of 153-153.5, 165 and 165.1-166.5, and each age group is represented within the height groups. Each image has a code to identify the participant and their pattern (this the oval shaped white label at the bottom of each participant's image).

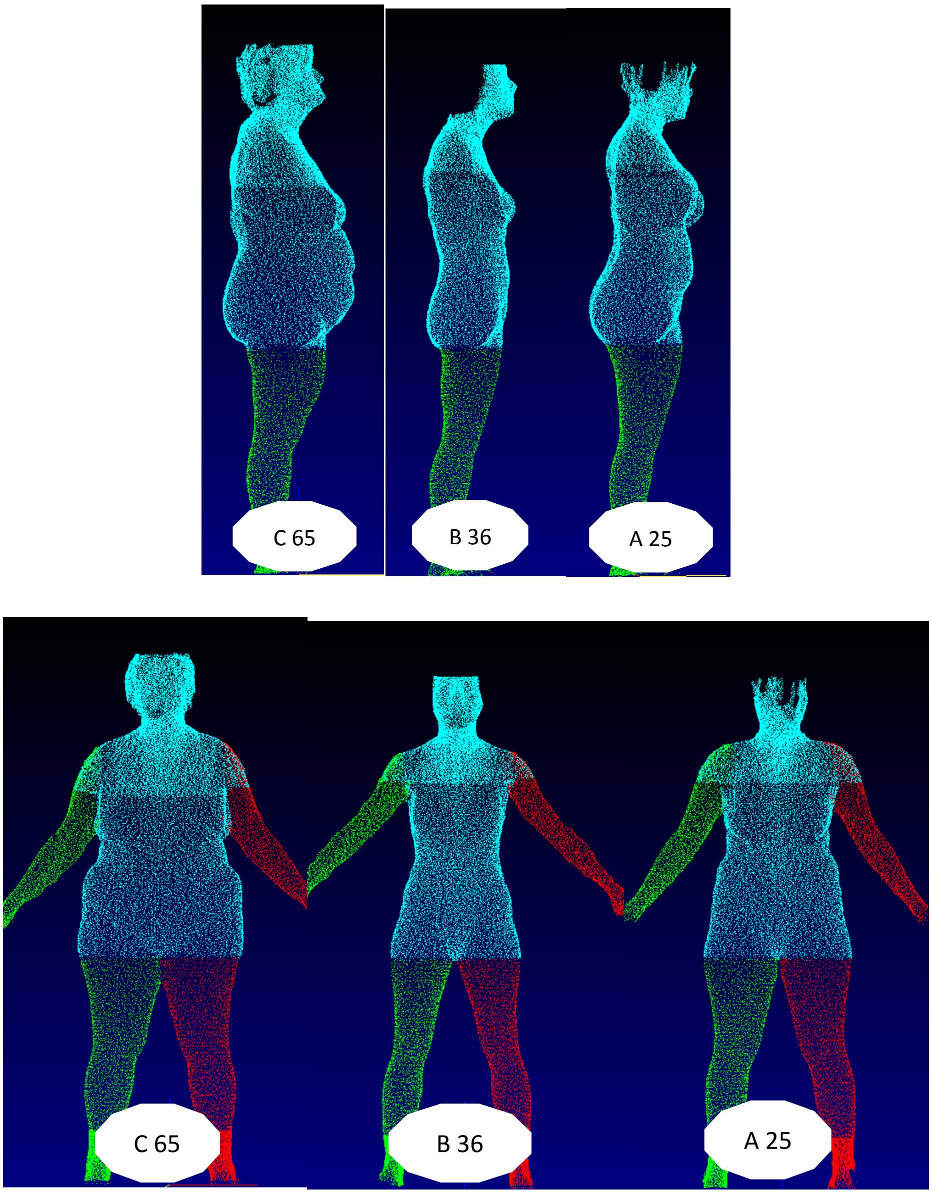


Figure 4-62 Scan images of participants from height grouping 153 -153.5

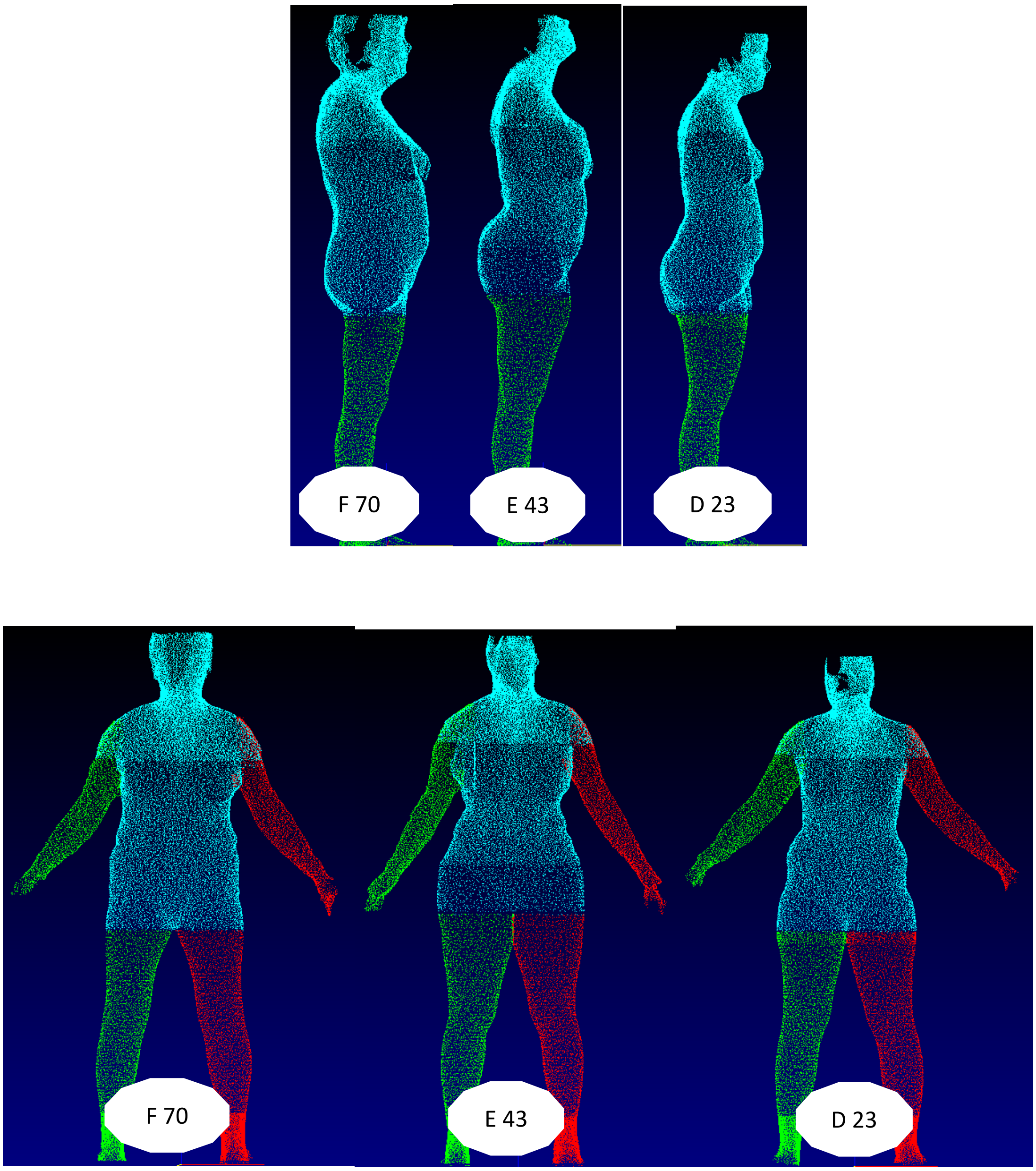


Figure 4-63 Scan images of participants from height grouping 165

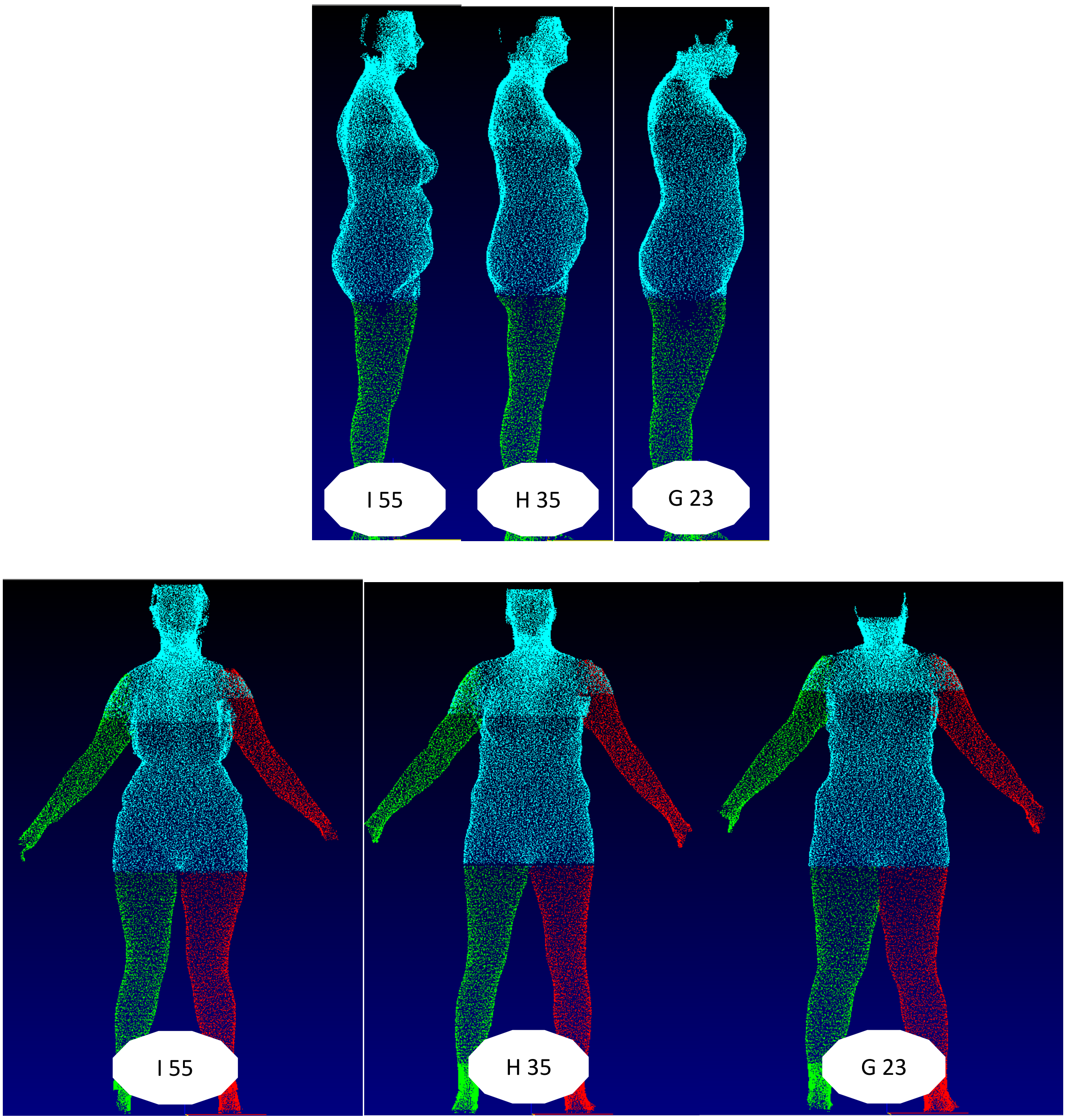


Figure 4-64 Scan images of participants from height grouping 165.1-166.5

4.8.3 <u>Documented characteristics of the nine participants chosen for bodice pattern development</u>

As mentioned above each participant was given a code for identification purposes. The code can be seen in row 1 of *Table 4-28* and is a letter appended with the participant's age. This codes will be used throughout this section to refer to individual participants and their patterns.

The characteristics of the nine participates chosen for pattern development were document by this research as follows:

Code	Age	Body shape	BMI	Height group	Nape to crotch W11-W26
A 25	25	bottom hourglass	27.5 (overweight)	153-153.5	65.5
B 36	36	rectangle	21.4 (normal weight)	153-153.5	64.0
C 65	65	triangle	37.3 (overweight)	153-153.5	67.0
D 23	23	bottom hourglass	25.6 (overweight)	165	69.0
E 43	43	bottom hourglass	30.1 (obese)	165	71.0
F 70	70	rectangle	29.1 (overweight)	165	71.0
G 23	23	hourglass	31.2 (obese)	165.1-166.5	69
H 35	35	rectangle	24.1 (normal weight)	165.1-166.5	66.0
I 55	55	bottom hourglass	25 (normal weight)	165.1-166.5	68

Table 4-28 Characteristics and categorisations of the nine participants selected for pattern development

Of the nine participants chosen, only three (participants B36, H35 and I55) had BMI scores that placed them within the normal weight category (*Table 4-28*). Interestingly, these three participants were within the 35-45 and 55+ age clusters and not as expected from the youngest age cluster.

The youngest age cluster had two participants with BMI scores that placed them in the overweight category (A25 and D23) and one participant placed in the obese category (G23). Upon consideration of the previous results of the CDVELA for the entire sample (4.7), it suggested that a high BMI score could have been the factor that made these participants have two or more landmark errors, which, in turn, made these participants eligible for pattern selection as outlined in section 3.14.2 of the methodology. The youngest age cluster all manifested body shapes with a clearly defined waist (*Table 4-28*) and so reason dictated that there should be no problems with the waist positioning and measurement on the pattern.

4.8.4 Determining each participants torso length and comparing this on the pattern

Dealing first with the participants measurements from the scanner. This research first calculated the nape (7th cervical) to crotch measurement. This was done using two length measurements – the back neck height to the floor and the crotch height to the floor. This meant these measurements were straight vertical measurements and did not follow the contours of the body. Crotch height was subtracted from the back neck height and produced the nape to crotch measurement above (*Table 4-28*).

The calculation was undertaken after the SLVM process to ensure that the nape and crotch points were placed accurately. This calculation was developed to see the difference in back torso lengths between participants in each height grouping as it had previously been stated that mature women can lose height due to the change in spinal architecture (Sorkin *et al* 1999).

Although participants were grouped into particular height sets it appeared that their nape to crotch lengths were all different with no strong pattern to indicate each age group had a particularly long or short nape to crotch measurement. Indeed, the nape to crotch measurement was not very different between each of the height clusters.

Women lose height as they age due to changes in the spines architecture (Croney, 1980; Sorkin *et al* 1999) and research had shown their torso length, especially at the back may be longer (Richards, 1980), yet this was not apparent in this data set. Referring back to the CDVELA notes (Appendix R), it appeared that none of the participants from the 55+ age cluster had an overtly stooped posture, which could account for height loss. This could have been the reason why there were not marked differences in nape to crotch height measurements between the age groups. Therefore, it could be reasoned that if an older women manifested an upright posture as she ages her torso length at the back will be less changed, in terms of geometry and measurement, than that of a younger women. This has positive implications in terms of finding garments that fit.

The pattern images below in*, Figure 4-66* and *Figure 4-67* are presented in their height categories. Each height category contains 6 patterns (two patterns per participant). The age of each participant's and their pattern is represented by a colour as detailed in *Figure*

4-60 and shown as an example in *Figure 4-61*. One of the two patterns is developed from unmodified scan data and the other modified scan data as detailed in *Figure 4-60* and *Figure 4-61*. The patterns have been laid over each other so the viewer can see how the geometry/shape of the pattern differs depending on age, body shape or landmark modification.

The images of patterns *, Figure 4-66* and *Figure 4-66* below illustrate that variance in nape to waist height between participants who share the same or similar overall height impacts on pattern geometry and more specifically length. These images also show that movement of the centre back waist landmark within the CDVELA process also alters the overall bodice pattern length as shown in the pattern images with an unbroken line.

Bodice length varied between the participants within the same height grouping and this impacted on the pattern length as mentioned above and illustrated in, Figure 4-66 *and* Figure 4-67*. This demonstrated that segment lengths between key measurements such as bust to waist are as important as the circumference measurements themselves.*

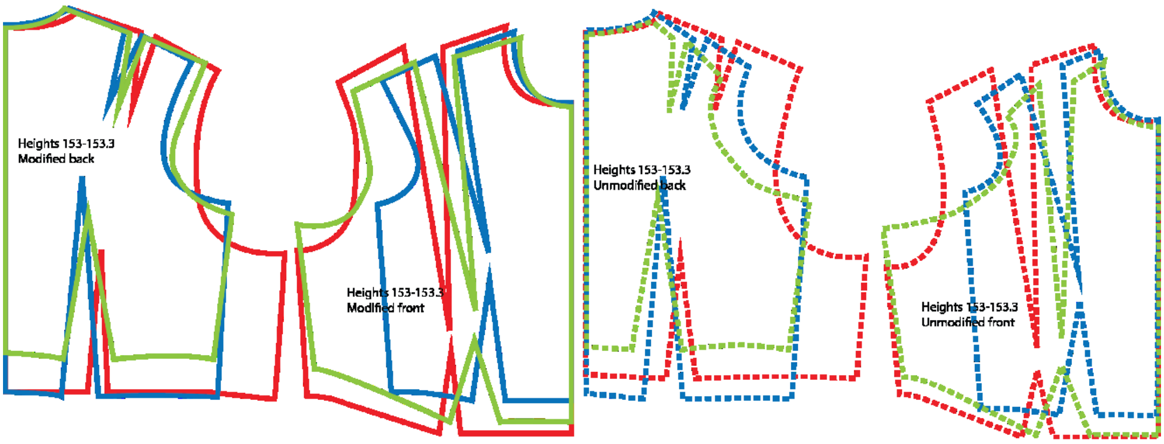


Figure 4-65 The spread of nape to waist different bodice lengths for participants from height group 153-153.5.

Participant C 65 (*Figure 4-62)* from height group 153-153.5 had the longest bodice(the red patterns above) and nape to crotch length (*Table 4-28*). In fact, this participant mentioned she had a long torso when fitting the bodice toile (demonstrating her excellent proprioceptive knowledge) but this will be discussed large in this chapter when covering the findings of toile fitting. Their bodice (the red pattern) was the largest of the three bodices and required the least amount of suppression with the smallest darts. This participant was categorised as being overweight and displaying a triangle shape. The waist was modified and the CB length now matched the length of participant B 36's bodice (blue modified pattern).

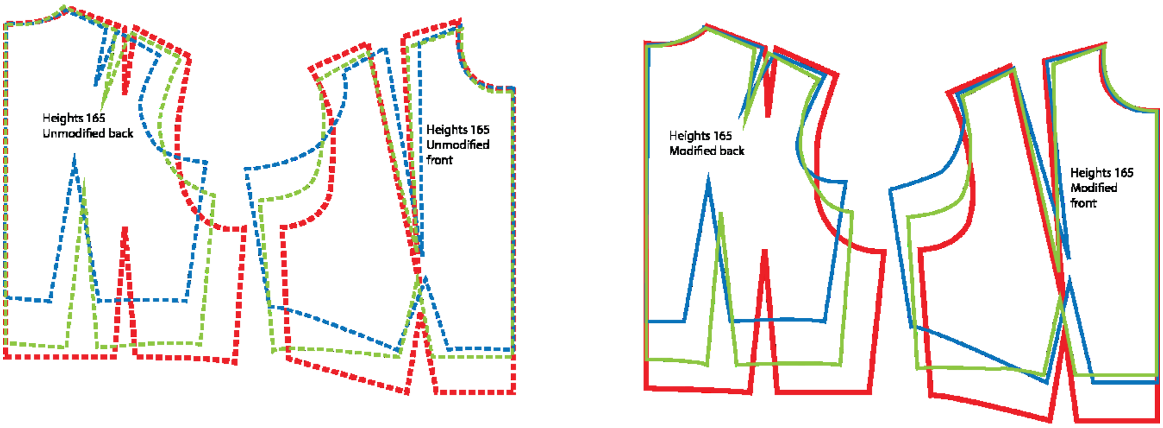


Figure 4-66 The spread of nape to waist different bodice lengths for participants from height group 165.

Participant F 70 (*Figure 4-63*) in height group 165 (*Figure 4-66*, the red patterns above) had the longest bodice length and longest nape to crotch length (*Table 4-28*). However, participant E 43 (*Figure 4-63*) had the same nape to crotch measurement (*Table 4-28*) yet their bodice length (the blue patterns) was the shortest. This indicated a high waist position and demonstrated that not all waist positions are the same even if participants share similar height.

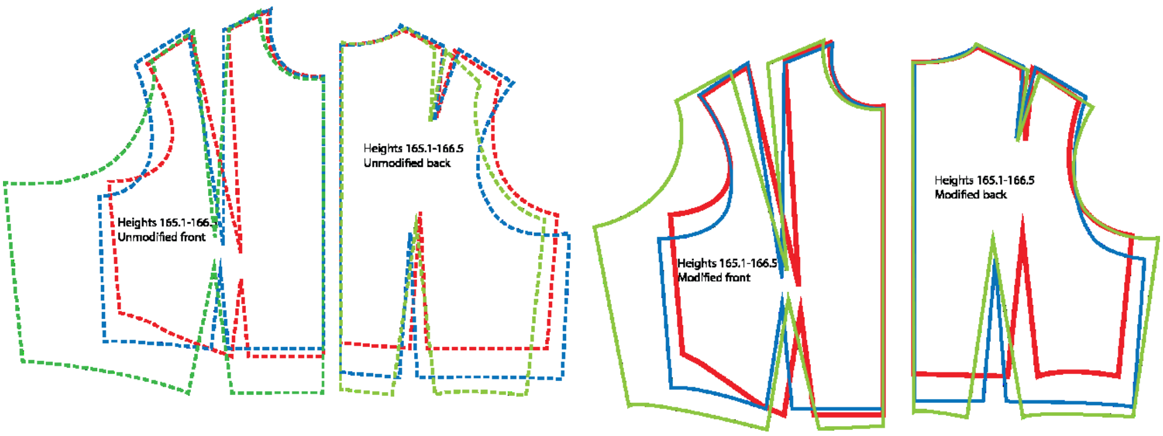


Figure 4-67 The spread of nape to waist different bodice lengths for participants from height group 165.1-166.5.

Nape to crotch length and bodice lengths were again mixed in their measurements for height group 165.1-166.5 but this grouping had a greater spread of overall height than the other two height groups. Participant I 55 was classified as a bottom hourglass (*Table 4-28*) and her scan image (*Figure 4-64*) shows that she was narrow directly under the bust and she had a low bust point. As a result her pattern shaping at the CF dipped and there was an acute angle along the front hemline reaching the side seam (*Figure 4-67* the red patterns).

4.8.5 A lower bust point

Additionally, comparison of each pattern from each height cluster indicated that participants from the 55+ age cluster had lower bust points even if they were classed as having a normal weight BMI rating. This is significant as the bust is a key body measurement as it is a region of the female shape which protrudes. It has previously been established that garments targeted at a mature demographic were cut to fit a younger body shape (Birtwistle & Tsim, 2005) and this research established, via the questionnaire, that the bust region was reported by participants as the second area of the body (after the waist) to have issues regarding fit (4.4.6). Therefore, this research concluded that a low bust point is more common in mature women and that the shaping of the bust needed to be lower on the garment. This research also recommends that retailers catering for this demographic address bust positioning and shaping within their pattern blocks to reduce fit issues for this portion of the body. It also recommends the bust point be closely scrutinised within the SLVM and CDVELA processes with perhaps the addition of a visual aid to enable participants to indicate their preferred bust point position and type of lingerie worn.

4.8.6 Issues with armhole size and shaping using unmodified scan data

Although all measurements had been taken to construct the 18 bodices (*Figure 4-58*) it became apparent that Beazley and Bonds (2003) method, when combined with erroneous measurements (from the unmodified scans), made plotting the shoulder angle and shaping the front and back armhole problematic. This was because their pattern method (like many other published methods) uses a rectangle perimeter with dimensions that were determined by nape to waist length and a half of the bust circumference plus 1.5cm suppression for the waist dart (*Figure 4-69*). Most of the measurements (apart from the back neck rise, over bust to waist and waist shaping) were contained within this rectangle by this research.

4.8.7 Pattern method and measurement issues impacting on armscye shaping and shoulder length

This section will commence by showing what a correctly landmarked shoulder should look like. The shoulder landmark should be placed at the sight of angle change to ensure the shoulder slope is measured correctly for clothing development. The correct sight of angle change is shown below in *Figure 4-68* (the image with red marker on the shoulder).

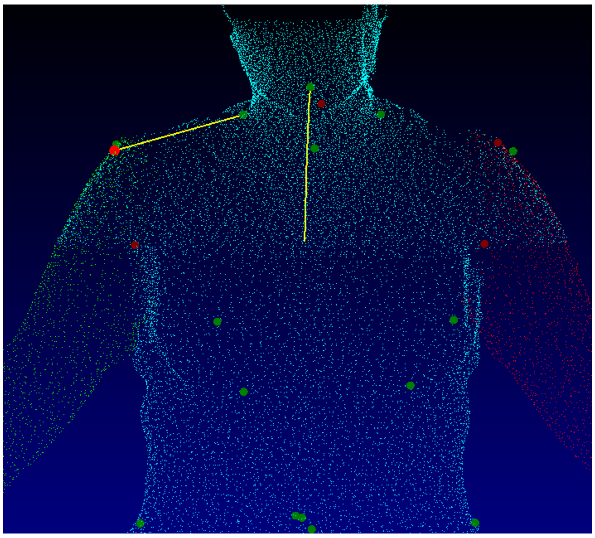


Figure 4-68 Correct shoulder landmark placement (modified during the SLVM process) for participant G 23

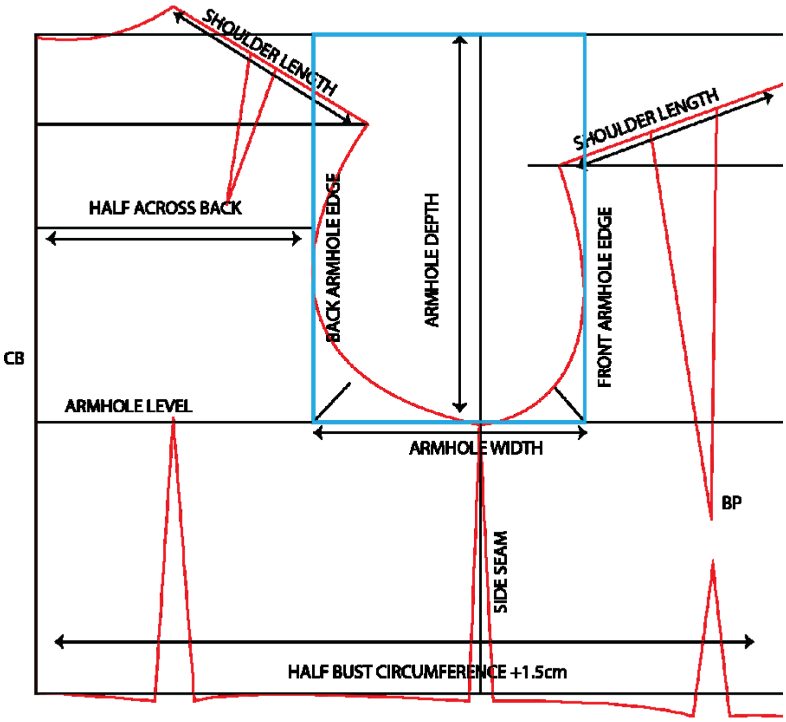


Figure 4-69 Beazley and Bond's (2003) method of armscye/armhole construction and shaping

With reference to *Figure 4-69* above the armhole level, side seam, across back, and front/back armhole all use the CB (centre back) vertical line as the commencement point and were either measured or drafted out from this line depending on whether it was a horizontal or vertical measurement. This meant that the CF (centre front) vertical line was present but was only used to plot the front neckline depth and width. Although an across front measurement was listed in the measurements required for this pattern method it was not actively used by the method which is surprising as it would seem pointless to include it in the list of measurements if were not to be utilised.

Armhole size and shaping were plotted within the rectangle's perimeter by this research. The armscye was plotted using:

- Armhole depth measurement (to show how deep to make the armhole),
- Front and back armhole (to show how wide to make the armhole) and
- Shoulder length

All of these measurements form a second smaller rectangle within the larger over all rectangle perimeter as shown in *Figure 4-69* and highlighted as a blue rectangle.

This research found that issues arose if the shoulder landmark was not placed exactly on the sight of angle change as shown below in *Figure 4-70* and was placed either too high (near to the side neck point) or too low (down the upper arm). This meant the subsequent shoulder length measurement was either too short or too long and this impacted on the armscye/armhole shaping as will be discussed below in detail. This would result in the armhole shape not sitting comfortably within the blue rectangle and the curved shape of the armhole would either be too scooped and short at the back and too shallow and long at the front (

Figure 4-74 *Unmodified* patterns showing erroneous armscye/armhole shaping for participants G 23, B 36, A 25 and E 43. Green = 18-25 and blue = 35-45 years of age

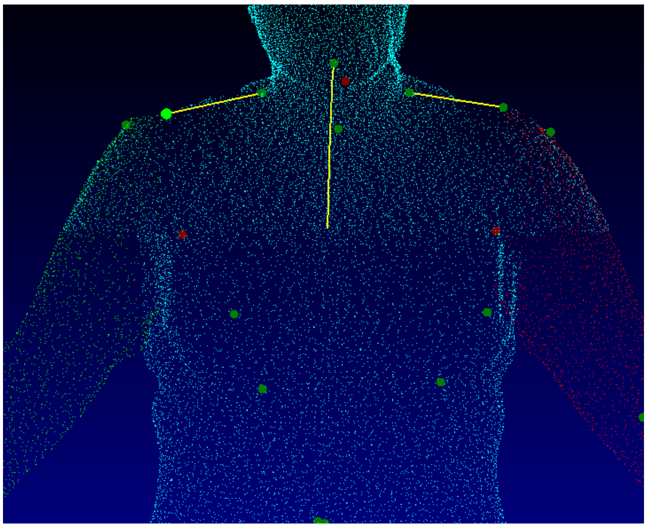


Figure 4-70 Incorrect shoulder landmark placement (identified during the SLVM process) for participant G 23

The images below showing participants G23, A25 and B36 (*Figure 4-71*; *Figure 4-72* and *Figure 4-73*) showed how erroneous landmarks appeared on the participants (during the SLVM process) who had both high and low BMI scores (*Table 4-28*). All the images show the surface to be rough and the patching at the armpit junction and along the shoulder line is visible. There are also occlusions on *Figure 4-73* at the armpit. These errors have clearly impacted on the accuracy of the landmark placement which when used for pattern construction have given peculiar armscye shaping as illustrated

Figure 4-74 Unmodified patterns showing erroneous armscye/armhole shaping for participants G 23, B 36, A 25 and E 43. Green = 18-25 and blue = 35-45 years of age

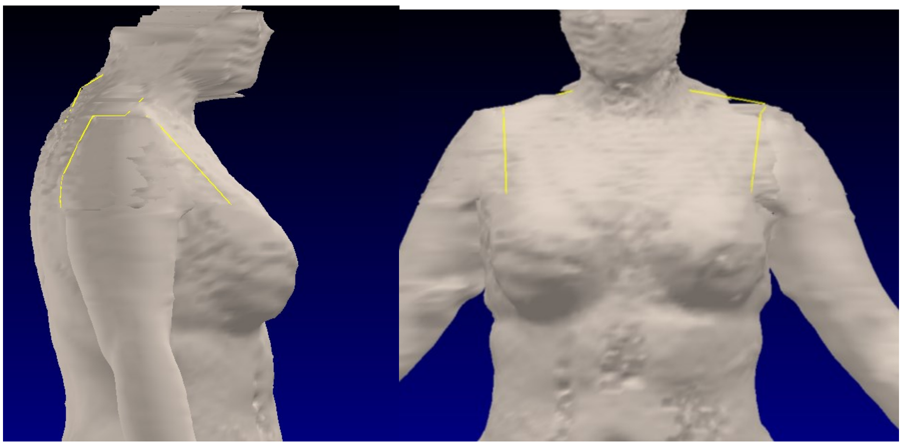


Figure 4-71 Participant G 23 Erroneous front armpit and shoulder point landmarks (shown in yellow)

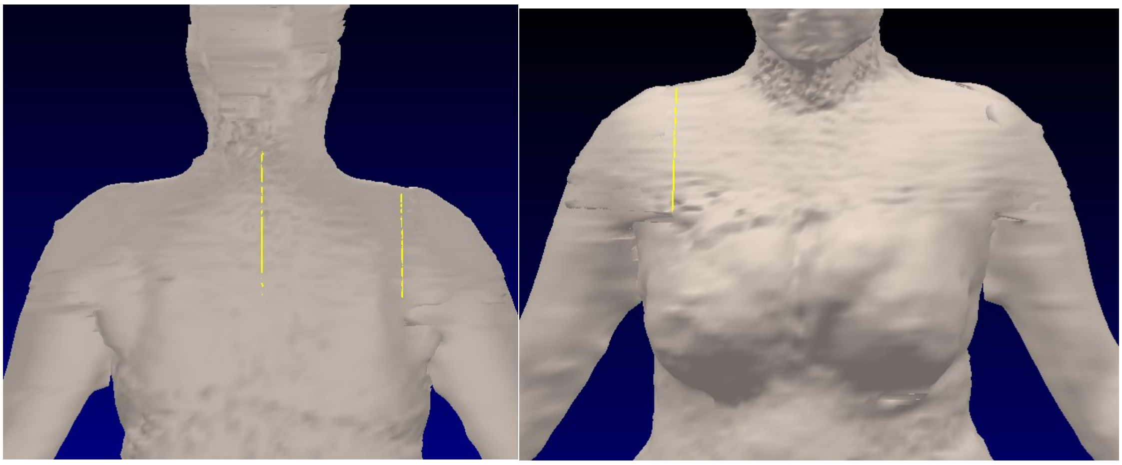


Figure 4-72 Participant A 25 Erroneous front, back armpit and shoulder landmark positions (shown in yellow)

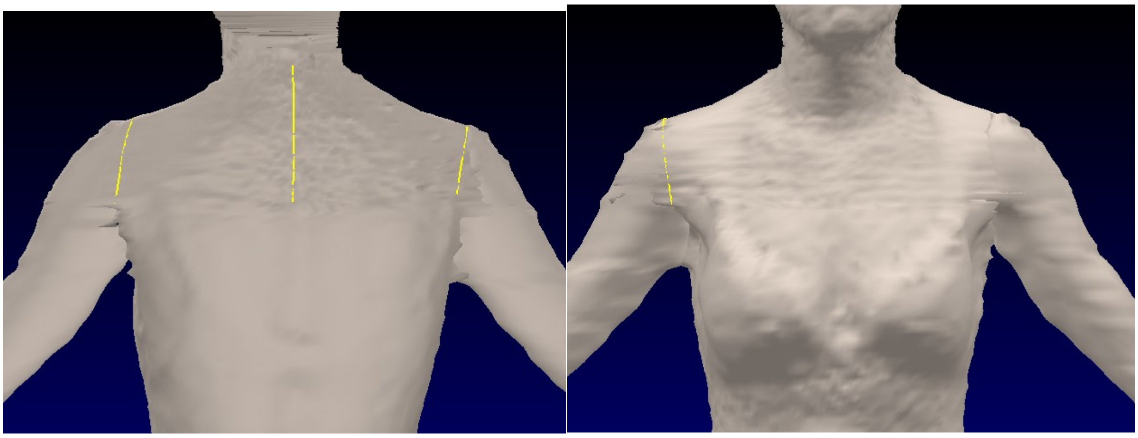


Figure 4-73 Participant B 36 Erroneous front, back armpit and shoulder landmarks (shown in yellow)

Figure 4-74 below show the patterns that were made using unmodified scan data for G23, A25 and B36. It also show the pattern for E43. This research found that when the shoulder landmark was placed erroneously (in these cases to high on the shoulder slope nearer to the side neck point) the resulting armhole shaping on the front bodice (G23, A25 and E45) showed a short shoulder line which would not adequately cover the shoulder to the point of angle change and a long but shallow scooped armhole area towards the side seam which would leave insufficient room for the shape around the armpit and would either cut into the armpit or gape.

B36 pattern shows the armhole shaping as small and the underarm is high when compared to the length of the side seam. The shoulder length is also too short because the landmark was not placed at the sight of angle change.

Figure 4-74 Unmodified patterns showing erroneous armscye/armhole shaping for participants G 23, B 36, A 25 and E 43. Green = 18-25 and blue = 35-45 years of age

At present most scanners use a similar size of resolution (*Table 2-1*), perhaps to keep file sizes small. However this research recommends that to avoid the above errors in shoulder landmark placement shown in *Figure 4-71, Figure 4-72 and Figure 4-73* every brand of scanner used for anthropometric purposes needs to ensure they capture images with a high resolution to avoid a rough surface and to enable the software to detect the subtleties of the surface terrane (as manual measurement approaches do via palpation *Figure 4-16*) to enable better landmark positioning. The correct sight of angle change is shown below in *Figure 4-68* (the image with red marker on the shoulder).

The academic experienced in pattern construction who had validated these patterns (as discussed in section 3.15.2) identified these errors very quickly and reported that *'The shoulder is too narrow and has distorted the armhole shape*' (Appendix W). They also commented *'When fitted this block would look like a cut-away sleeve and would be problematic for set in sleeves*' (Appendix W).

The patterns which have used modified scan dimensions (*Figure 4-75*) show a marginal improvement in armhole shaping and shoulder length as shown in this comment: '*The armscye shaping looks improved and the shaping is flatter on the back arm hole and gently scooped out at the front armhole which is what is expected on a pattern*' (Appendix W). This response demonstrated that the SLVM and CDVELA processes were effective in improving shoulder length, the armhole shaping as well as providing a means to diagnose why the landmarking/measurement error occurred initially.

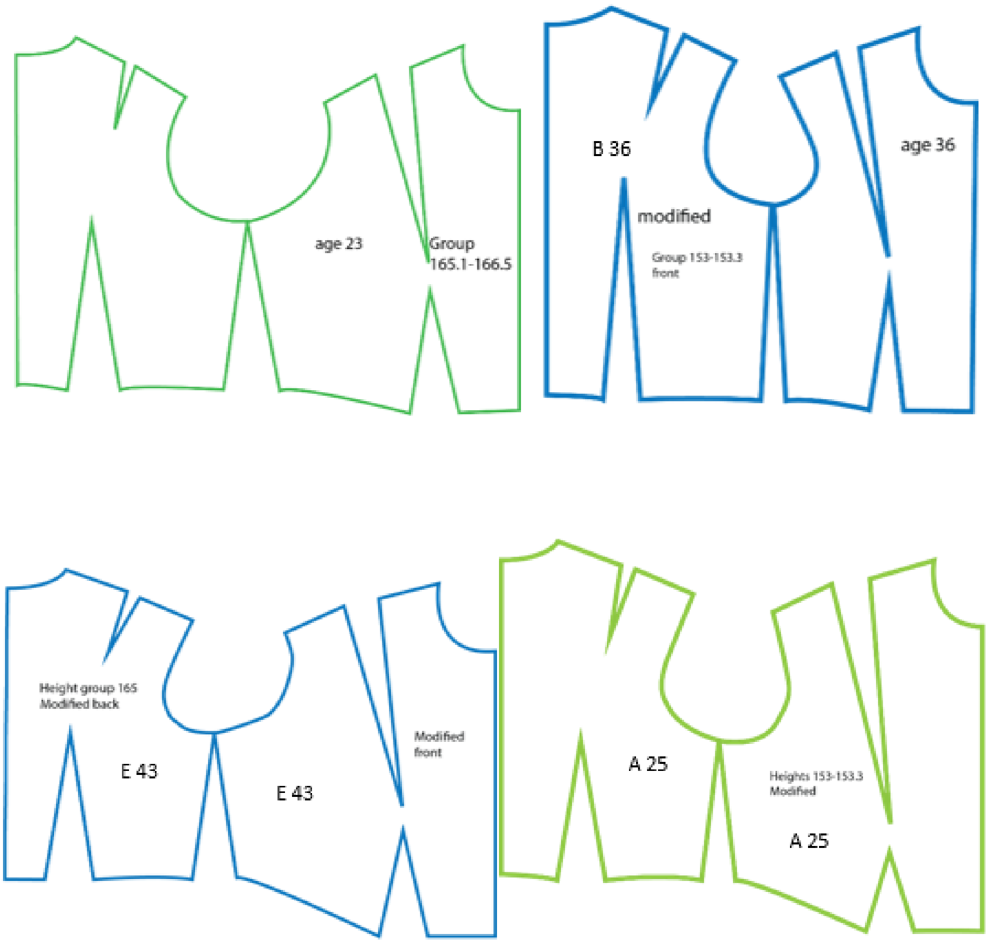


Figure 4-75 Modified (solid line) patterns showing improved armscye/armhole shaping for participants G 23, B 36, A 25 and E 43. Green = 18-25 and blue = 35-45 years of age

4.8.8 Pattern length and waist landmark modification for the participants aged 55+

Participants C65, F70 and I55 all had waist landmark modification. All participants had requested to have waist landmark definitions that were lower on their body than that of the MMU 03_4cm_tolerance MEP or definition B in Table 3-5. Prior to waist landmark modification the scanner had placed their waist on the under bust even though they varied in BMI and body shape (*Table 4-28*). This is noteworthy as one of the participants (I55) was classed as a normal BMI and bottom hourglass and, by definition, had a discernible waist (Table 3-10). It was therefore reasonable to expect that the scanner would have had no problem placing this landmark in the correct position. However, the CDVELA notes revealed *'[The] waist is placed at under bust although this is the narrowest point on the torso*' (Appendix R; 26.1.1). This research found, therefore, that the narrowest point on the torso overlapped within the 4cm tolerance provided by the MEP to mark the waist landmark. Therefore, this research theorised that to ensure the waist landmark was lower down on the body the SizeUSA MEP, which uses a smaller 2.5cm tolerance, would be more effective for this participant's body shape.

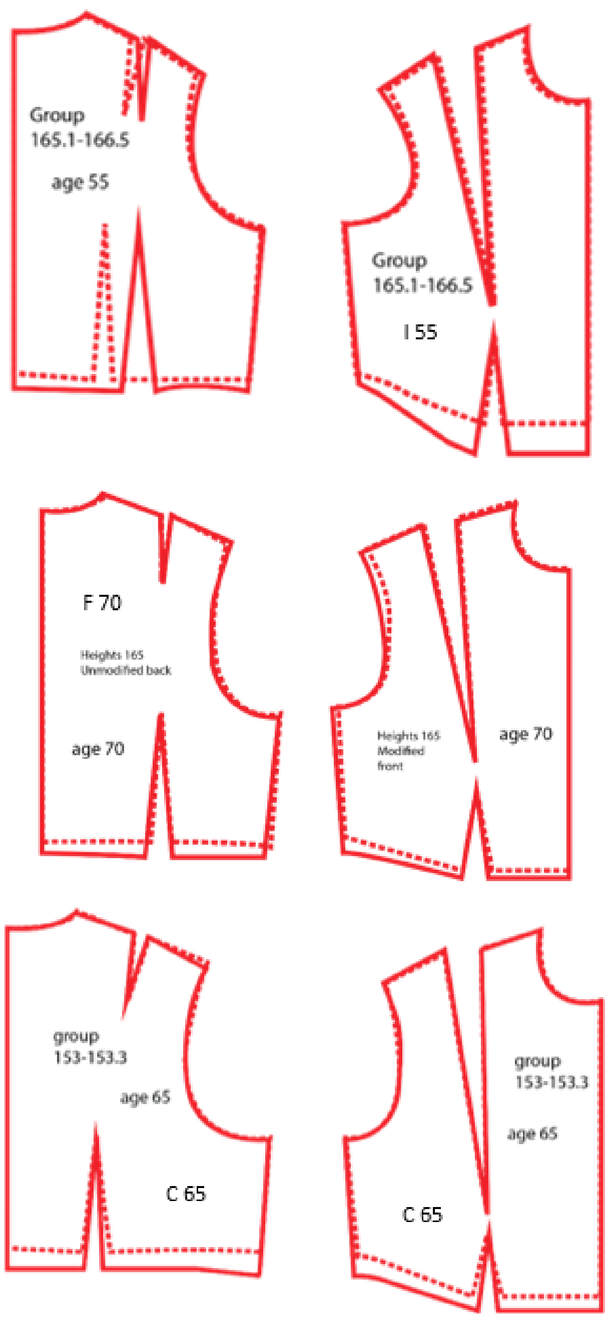


Figure 4-76 Both unmodified and modified patterns overlaid to compare pattern geometry/shape change

The back waist landmark was the point chosen to be moved to modify waist positioning on the scan. However, observation of the unmodified and modified patterns showed that because of the over bust to waist measurement this meant that some of the CF lengths dipped (I55's pattern does so considerably) and the depth of change on the CF hem appeared greater than that of the CB as illustrated in *Figure 4-76* above. Veitch (2012) states that pitched waistlines maybe more appropriate for participants who do not display a standard body morphology and pattern development using direct measurements would seem to support this. However fitting the pattern would truly demonstrate it appropriateness through the responses of the wear.

Beazley and Bond's (2003) over bust measurement (which begins at the side neck point, over the point of greatest prominence and to the waist, 11.1.2) was an ideal measurement for an older women as age-related morphological change could make the breast larger and heavier, making the bust point lower. This change in size and shape on the front of the body indicated that surface lengths increase to amply cover the breast area and allow the waistline to sit comfortably below the bust. This also indicated that suppression of the waist and bust needs consideration.

The academic pattern practitioner commented about the front and back pattern lengths: *'The waist is still dipped deeply at the front but again this is because measurement G is a significantly longer measurement than nape to waist'* (Appendix W) but they remarked that this could due to the prescribed method of drafting and measurements used and this research concurs.

4.8.9 Waist landmark modification pattern shape and the younger demographic

Interestingly the waist landmark had to be modified for A25 and H35 of the younger demographic (which will be discussed below); demonstrating the landmarking error for the waist is not limited to older women.

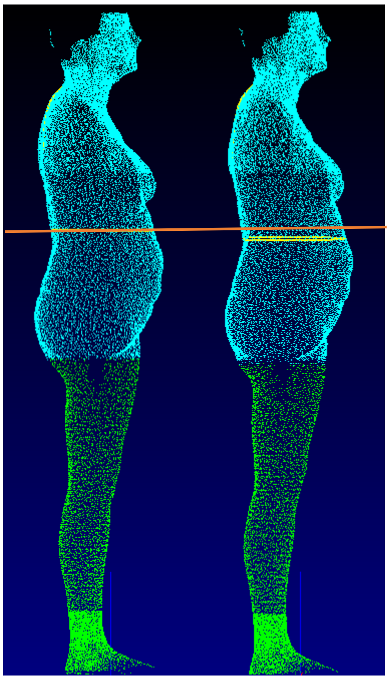


Figure 4-77 Participant H35 waist landmark modification (red line shows unmodified waist landmark position and the yellow the modified waist landmark position)

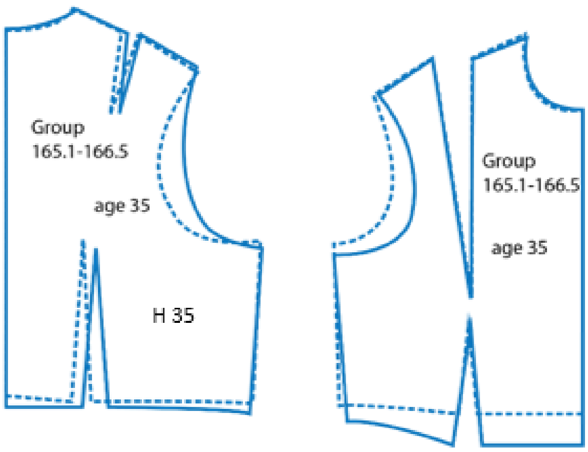


Figure 4-78 Pattern for participant H35 showing waist position modification.

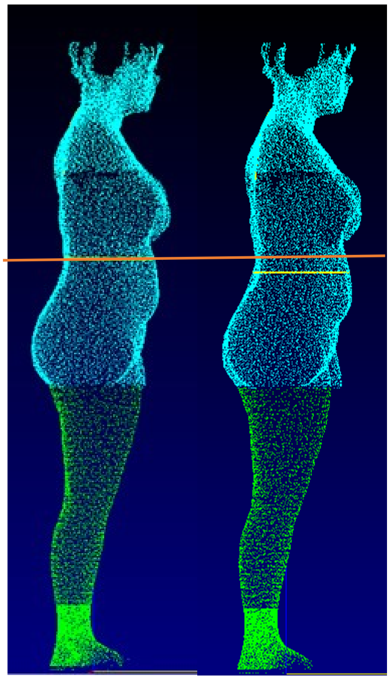


Figure 4-79 Participant A25 waist landmark modification (the red line shows unmodified waist landmark position and the yellow the modified waist landmark position)

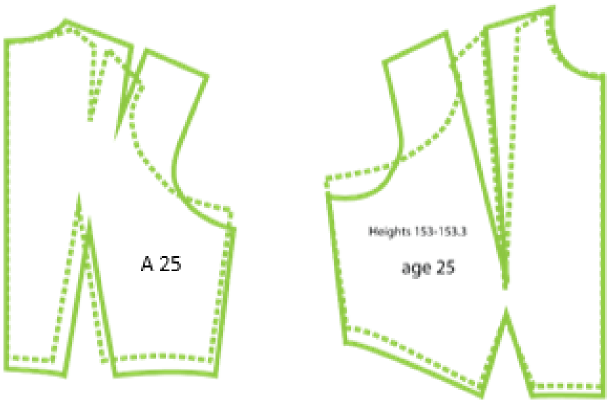


Figure 4-80 Pattern for participant A 25 showing waist position modification.

Waist landmark modification for participants A25 and H35 involved moving the CB waist landmark down the torso, more towards the small of the back as shown in *Figure 4-77*; and *Figure 4-79*). Participant A25, was classified overweight and a bottom hourglass shape (*Table 4-28*).

The CDVELA's notes provided more information as to the reason for waist landmarking modification as both categorisations are not uncommon in the sample frame of this research. The notes were as follows: *'[S]ubject's narrowest point on the torso appears near the under bust. They have a thick waist which continues downwards to the low hip and buttock region'* (Appendix R, section 26.1.3: row 56; *Figure 4-62*). Therefore, this research found that despite the participant being a bottom hourglass and classified as having a discernible waist (Table 3-10), the fact that they were classed as overweight and manifesting a thickened waistline meant the scanner placed the waist incorrectly at the under bust region.

Participant H35 also had the waist landmark moved further down the body (*Figure 4-77*) which meant the modified pattern increased in length (*Figure 4-76*). Again, the CDVELA provided more detailed observations of the scan to ascertain why the waist needed modification. The notes indicated the scan had many occlusions but was still viable for analysis as these occluded areas did not impact on the landmarking or measurement extraction for the torso. The notes indicated that their spine was slightly curved at the cervical portion and there were multiple errors and patching around the armpit junctions (see Appendix R, 26.1.2: row 19). Although this 35 year old participant was classified as having a normal BMI they were a rectangle shape (*Table 4-28*) and, therefore, categorised as not having a discernible waist (Table 3-10).

This research concluded that as the waist landmark need to be moved downwards and more towards the small of the back the SizeUSA MEP - which has a lower tolerance of 2.5cm - would be more effective in positioning the waist for these participants. This finding aligned with the findings of Gill *et al* (2014b) whose study underlined that bodyscanning technology needed to facilitate a number of waist definitions within its database to cater for more diverse body shapes and dimensions.

4.9 The toile fitting sessions and toile fit feedback (Activities 29 and 30)

4.9.1 The results of the fitting process

This next section will present and discuss the toile fitting session and the feedback provided by the participant and the fit observer (*Figure 3-1, Table 3-2*: Activities 29, 30 and 31). Details of how the fit session was organised, and implements are outlined and discussed in section 3.16. Similarly details concerning the development and implementation the fit pro forma are also outlined and discussed in 3.16 of the methodology chapter.

This next section presents the findings using 360 degree photographs of the participants to show toile fit, and a tabular format to present the feedback notes from both the participant and the observer. Discussion of the findings will follow within its own sections.

Participant F70 first fitted on bodice one as shown in *Figure 4-81*.

Figure 4-81 participant F70 wearing bodice one which is based on unmodified scan measurements

The following notes were taken by the observer concerning toile one's fit (*Table 4-29*).

Participant F 70		
Based on unmodified scan measurements (bodice one)		
Pattern region	Participant Comments	3rd party observation of bodice fit
Neck opening	*I would like it more scooped but it is ok.*	*(viewed front on) The neck sits high on at the CF, should be able to see a part of the sternal notch.*
Chest width	*Seems fine*	*(viewed front on) There is no visible pulling or excess fabric across the chest so would pass as ok.*
Back width	*Yes, feels fine*	*(viewed front on) Set lines are radiating from the back armhole and pointing at the shoulder blades indicating it is too tight in this region.*
Bust circumference	*It feels tight, would be better with more room across here (points to across the bust points).*	*(viewed side on) The seaming on the bra is visible and there are set lines radiating from the bust point indicating the garment is too tight across the breasts.*
Bust dart length	*ok*	*(viewed side on) Length of the bust dart stops approximately 2.5cm away from the bust point which is acceptable. The bust dart is suppressing the fabric above the breasts and therefore is effective.*
Bust shape positioning	*Yes it fits ok but isn't the waist dart high?*	*(viewed both side and front on)The waist dart is not suppressing the fabric underneath the bust enough and this area looks baggy and loose.*
Waist circumference	*Ok but the waist is a bit high, you can see my navel (participant pulls up trousers).*	*(viewed 360) Too loose, fabric buckling under the bust and participant is standing straight up.*
Waist dart	*Too high*	*(viewed front and side on) Waist dart is not suppressing the fabric it is ineffective.*

Waist positioning	*The waist is too high for me.*	*(viewed front and side on) The waist is too high when compared to the waistband of the trousers. Participant pulled at the hem consistently.*
Shoulder length	*The shoulders are a good fit*	*(viewed front on) The shoulder edges appear to sit at the point of angle change on the arm*
Armhole fit	*ok*	*(viewed side on) The armhole appears slightly high at the armpit point.*

Table 4-29 Participant age 70 - comments of toile fit for bodice one

Participant F70 then fitted on bodice two *Figure 4-82* below.

Figure 4-82 participant F70 wearing bodice two which is based on modified scan measurements

The following notes were taken by the observer concerning toile two's fit (*Table 4-30*).

F 70		
Based on modified scan measurements (**bodice two**)		
Pattern region	Participant Comments	3rd party observation of bodice fit
Neck opening	*Not as high as bodice one, though my taste is for a lower neckline.*	*(viewed front on) The fabric is collapsing at the neck edge. Zip has been poorly inserted.*
Chest width	*It's fine*	*(viewed front on) Fabric is sitting smoothly across the front of the chest. No issues here.*
Back width	*It's ok but if this were a blouse I would like it a bit looser.*	*(viewed front on) Smaller set lines are radiating from the back armhole and pointing at the shoulder blades indicating it is too tight in this region, though not as tight as bodice one.*
Bust circumference	*It still feels tight, perhaps it is because I have put on some weight.*	*(viewed side on) bras seaming is still visible and there are set lines radiating from the bust point indicating the garment is too tight across the breasts.*
Bust dart length	*It seems fine*	*(viewed side on) Length of the bust dart stops approximately 2.5cm away from the bust point which is acceptable. The bust dart is suppressing the fabric above the breasts and therefore is effective.*
Bust shape positioning	*Its ok*	*(viewed both side and front on) The shaping of the bodice appears to follow the shaping of the bust.*
Waist circumference	*Ok it feels tighter than the other one (bodice one)*	*(viewed side on) the fabric is not compressing the skin but perhaps an addition of 0.7cm of ease to each side seam would provide more comfort.*
Waist dart length	*Yes it is ok, it gives me shape (participant is admiring her shape in the mirror).*	*(viewed front and side on) Waist dart is suppressing the fabric under the bust and gives the participant definite shaping under the bust and on the waist.*

Waist positioning	*It feels comfortable*	*(viewed front and side on) The waist is still rather high when compared to the waistband of the trousers, although it is lower than bodice one.*
Shoulder length	*The shoulders are a good on this (participant pats shoulders)*	*(viewed front on) The shoulder edges appear to sit at the point of angle change on the arm and there is sufficient ease for a sleeve insertion.*
Armhole fit	*There is plenty of room*	*(viewed side on) The armhole appears to have good shaping and sufficient ease.*

Table 4-30 Participant F70 - comments of toile fit for bodice two

Participant I55 first fitted on bodice one as shown in *Figure 4-83* below.

Figure 4-83 Participant I55 - wearing bodice one which is based on unmodified scan measurements

The following notes were taken by the observer concerning toile one's fit (*Table 4-31*).

I 55		
Based on unmodified scan measurements (bodice one)		
Pattern region	Participant Comments	3rd party observation of bodice fit
Neck opening	*It is ok*	*(viewed front on) The neck sits slightly high on at the CF, should be able to see a part of the sternal notch.*
Chest width	*It's ok*	*(viewed front on) No visible pulling or excess fabric across the chest so would pass as ok.*
Back width	*ok*	*(viewed front on) The fabric is smooth and there seems to be sufficient ease*
Bust circumference	*It is tight and feel tighter on the back (participant moves arms around in a circular motion).*	*(viewed front on) The fabric is collapsing slightly above the right breast indicating that one breast is higher than the other.*
Bust dart length	*It feels too long*	*(viewed front on) The dart length appears correct for the left breast but too short for the right.*
Bust shape positioning	*It doesn't feel comfortable, there isn't room around here (points towards bust points).*	*(viewed both side and front on) The bust positioning is correct for the left breast but too high for the right.*
Waist circumference	*Too high, you can see my bra (raises arms and laughs).*	*(viewed 360) The waist is too high and bodice length does not sufficiently cover the under bust and waist regions of the body.*
Waist dart	*Too short*	*(viewed front and side on) Waist dart is not suppressing the fabric at the front and is ineffective. Waist dart on the back appears effective.*
Waist positioning	*The waist position here is very high, it look more like a cropped top! Is it supposed to go up at the sides?*	*(viewed front and side on) The waist is too high when compared to the waistband of the trousers.*
Shoulder length	*Ok*	*(viewed front on) The shoulder edges appear look slightly short (a matter of 1cm or so) of the point of angle change on the front of the body.*

Armhole fit	*Very tight, I usually have problems with the fit of armholes. As I have a large bust the armholes are sometimes too big.*	*(viewed 360) The armhole appears high at the armpit point. The fabric is collapsing slightly under the right armpit but looks looser on the left.*

Table 4-31 Participant I55 - comments of toile fit for bodice one

Participant I55 then fitted on bodice two as shown in *Figure 4-84* below.

Figure 4-84 Participant aged I55 - wearing bodice two which is based on modified scan measurements

The following notes were taken by the observer concerning toile two's fit (*Table 4-32*).

I 55		
Based on modified scan measurements (**bodice two**)		
Pattern region	Participant Comments	3rd party observation of bodice fit
Neck opening	*It is very good*	*(viewed front on) The neck edge looks flat and is not constricting.*
Chest width	*Across here is fine*	*(viewed front on) The fabric is sitting smoothly across the front of the chest. No issues here.*
Back width	*Comfortable, fine*	*(viewed front on) The fabric is smooth and there appears to be sufficient ease. Shoulder darts are supressing fabric around the shoulder effectively.*
Bust circumference	*It feels ok*	*(viewed 360) The fabric is smooth and perhaps there could be slightly more ease (0.5cm added to each side seam to allow for greater comfort in when the body is in motion.*
Bust dart length	*It feels too long*	*(viewed side on) The length of the bust dart stops approximately 2.5cm away from the bust point which is acceptable. The bust dart is suppressing the fabric above the breasts and therefore is effective.*
Bust shape positioning	*There is enough room for my boobs*	*(viewed both side and front on) The shaping of the bodice appears to follow the shaping of the bust.*
Waist circumference	*It is a bit loose but feels ok (participant puts hands on sides)*	*(viewed side on) The waist looks too tight when viewed from the back. There are set lines originating from the side seams pointing towards the CB which suggests the CB length is slightly too long and there is insufficient ease*

		to allow the zip to follow the curve of the spine.
Waist dart length	*ok*	*(viewed front and side on) Waist dart is suppressing the fabric under the bust and gives the participant definite shaping under the bust and on the waist.*
Waist positioning	*It is fitting on my waist.*	*(viewed front and side on) The waist is still rather high when compared to the waistband of the trousers, although it is lower than bodice one. The front of the bodice dips significantly when compared to the sides and back of the garment.*
Shoulder length	*Yes, it's fine here.*	*(viewed front on) The shoulder edges appear to sit at the point of angle change on the arm and there is sufficient ease for a sleeve insertion.*
Armhole fit	*The armhole still feels very tight, as I said before the armhole is always a problem for me.*	*(viewed side and front on) The armhole looks tight, too high at the armpit and cutting into the armpit junction. The armhole need reshaping, taking the underarm down by approx. 2-2.5cm to allow for arm movement.*

Table 4-32 Participant I55 - comments of toile fit for bodice two

Participant C65 first fitted on bodice one as shown in *Figure 4-85*below.

Figure 4-85 Participant C65 - wearing bodice one which is based on unmodified scan measurements

The following notes were taken by the observer concerning toile one's fit (*Table 4-33*).

C 65		
Based on unmodified scan measurements (bodice one)		
Pattern region	Participant Comments	3rd party observation of bodice fit
Neck opening	*Feels like it is a bit loose at the neck.*	*(viewed front on) The neck edge is not lying flat at the CF. CB has set lines originating at the CB zip and pointing towards the side neck point. This indicates the back neck needs reshaping to allow more room at the base of the neck.*
Chest width	*It looks a little loose here (pinches fabric around the chest area whilst looking in the mirror).*	*(viewed front on) Excess fabric at the x chest has caused slight buckling of the fabric. Too much ease.*
Back width	*This is ok.*	*(viewed front on) The fabric is collapsing around the back armscye*

		indicating the across back measurement is too long.
Bust circumference	*It feels a little snug, I prefect looser clothing around here.*	*(viewed front on) The garment looks tight across the bust, there are set lines above and below. There needs to be more ease around the bust point.*
Bust dart length	*I suppose it looks ok.*	*(viewed front on) The dart length appears correct and finishes approx. 2.5cm away from the bust point.*
Bust shape positioning	*It feels a little high, it is snug on my bust.*	*(viewed both side and front on) The bust positioning is too high for the participants bust and is compressing the bust. There are set lines originating at the front armscye and at the front hem which point towards the bust point. There are also set lines appearing on the bodice back near the bra band. This indicates the shaping is in the wrong place and should be lower to match the bust point.*
Waist circumference	*This seems ok.*	*(viewed 360) The waist circumference appears insufficient and the fabric is tight across the back bodice.*
Waist dart	*Ok, I suppose.*	*(viewed front and side on) The waist dart is suppressing the fabric too much at the back and under bust.*
Waist positioning	*I have a long body and often the waist doesn't sit right. This is very high for me.*	*(viewed front and side on) The waist is too high when compared to the waistband of the skirt. The front is dipping significantly when compared to the back. The*

		side waist is barely covering the bra sides.
Shoulder length	*I like the shoulders, they are a good length.*	*(viewed front on) The shoulder angle looks correct. The length finishes at the point of angle change.*
Armhole fit	*The armhole feels fine, plenty of room.*	*(viewed 360) The armhole is big enough and is not obstructing movement.*

Table 4-33 Participant age C65 - comments of toile fit for bodice one

Participant C65 first fitted on bodice two as shown in *Figure 4-86* below.

Figure 4-86 Participant C65 - wearing bodice two which is based on modified scan measurements

The following notes were taken by the observer concerning toile two's fit (*Table 4-34*).

C 65		
Based on modified scan measurements (bodice two)		
Pattern region	Participant Comments	3rd party observation of bodice fit
Neck opening	*Feels a bit loose*	*(viewed front and side on) The neck edge is pulling away from the base of the neck.*
Chest width	*Yes this feels ok*	*(viewed front on) Fabric is sitting smoothly across the front of the chest. There is sufficient ease.*
Back width	*That feels ok too, although I don't like that I can see my back fat.*	*(viewed front on) The fabric is smooth and there appears to be sufficient ease around the shoulder blades. Shoulder darts are supressing fabric around the shoulder well. The looks to be slight pulling of the fabric at the back near the bra band.*
Bust circumference	*It feels a little tight across my bust here (gestures to the bust point).*	*(viewed 360) The garment looks too tight around here. The fabric has set lines originating at the shoulders and at the under bust region which point towards the bust point. There are set lines in the fabric at the back which originate at the CB and point downwards towards the side seams and around to the bust point.*
Bust dart length	*It seems a little long, do you normally have darts here? (Gestures to the shoulder area).*	*(viewed side on) The length of the bust dart stops short of the bust point. Perhaps a more supportive bra was worn on the day of the scan?*
Bust shape positioning	*It seems ok there is a little room for my bust but I still prefer a looser fitting top.*	*(viewed both side and front on) The bust shaping and suppression of the bodice appears to be a little too*

		high for participant's the bust.
Waist circumference	*Its ok, I mean I can breathe in this.*	*(viewed side on) The waist looks tight when viewed from the back. There are set lines originating from the side seams pointing towards the CB.*
Waist dart length	*I suppose it is ok, it is giving me some shape here (gestures to waist region)*	*(viewed front and side on) Waist dart is too long and finished too near the bust point. The dart is providing some suppression under the bust and shows the participants curves when viewed side on.*
Waist positioning	*Much better than the other bodice but I still feel it needs to be a little longer. My skirt is on my waist and the top needs to be long enough to meet the skirt.*	*(viewed front and side on) The waist is still high when compared to the waistband of the skirt, although it is lower than bodice one. The front of the bodice dips slightly when compared to the sides. The waist edge on the back of the garment looks ok and it nearly meeting the skirt waistband.*
Shoulder length	*Perfect! Shoulders are great.*	*(viewed 360) Again, the shoulder edges appear to sit at the point of angle change on the arm and there is sufficient ease for a sleeve insertion.*
Armhole fit	*This is a good fit, I do have problems sometimes with the armholes.*	*(viewed side and front on) The armhole looks ok, although the right armhole has slightly too much fabric at the front. This is a result of the bust shaping too high and not because the armhole shaping is erroneous.*

Table 4-34 Participant C65 - comments of toile fit for bodice two

4.9.2 Discussion of the fitting process – comfort and fit

The fitting process was designed to be systematic and target portions of the garment which may be prone to miss-fit, hence, the fit evaluation pro forma (Appendix Y). The pro forma was useful as it enabled the fit process to progress swiftly and kept the focus on the garment, as this research wanted the participants to feel positive about their body and any issues of poor fit to be perceived as a result of problems with the garment and not their body size and shape. This was important as women from this demographic can be sensitive about their body and this research wanted to avoid a negative study of personal body cathexis. The fit pro forma also provided clear instructions (via the observer) on how to remedy poor fit within a pattern context, which is the desired result of a professional garment fitting session.

The fit of each toile was assessed by both the participant and observer with both viewing the garment from different perspectives, those being the sensory perception of how the garment feels and the visual perception of how the garment looks. The observer was limited to visual analysis of the garment only using the 'principles of fit' (first outlined in Erwin and Kitchen's (1969) book "Clothing for Moderns" and later used within Liechty *et al's* (2009) book which focuses on garment fitting and pattern alteration). This practice is often used in professional fit meetings (Wren and Gill, 2010, Appendix AD).

This research established earlier on in the work via the results of the questionnaire that women aged 55+ equated comfort to good fit (4.4.5, *Figure 4-21*). The fitting process provided insights into how this demographic assessed garment fit against their body size and shape and confirmed that they evaluate the garment both by the aesthetic and comfort aspects in that they consistently described how the garment the feels against specific body parts for example:

> *'It feels tight, would be better with more room across here (points to across the bust points)'*
>
> *'It is tight and feels tighter on the back (participant moves arms around in a circular motion).'*
>
> *'It feels a little tight across my bust here (gestures to the bust point).'*

Establishing that participants from this demographic use sensory evaluation against their body morphology to determine good fit was novel as previous studies, such as that of Bye and LaBat (2005), Schofield *et al* (2006) and Wren and Gill (2010) assessed or viewed the garment fit process from the perspective of the fit expert and not the participant. Gathering information on participant fit evaluation using the pro forma (Appendix Y) designed by this research provided valuable information for online retailers processing returns. This is because the pro forma (Appendix Y) prompted the customer to give pertinent information on specific areas of the garment, which could be traced back to the pattern.

4.9.3 Discussion of the fitting process – block aesthetic and fit

Some of the content of the responses indicated that the participants would have liked the bodice block to be styled differently. For example, there were comments that the neckline would have looked better lower (*Table 4-29*) and another participant stated they would have preferred the bodice to be loose fitting (*Table 4-32*).

Comments around the style lines and styling of the block support the conclusions of Güzel (2013), Hurd-Clarke *et al* (2009) and Richards (1981) (2.9.1) that this demographic had a firm idea of what they wanted aesthetically in a garment. It also demonstrated that this demographic understood how to use a garment as a mask or corrective medium for their body through comments such as *'[Waist circumference is] ok but the waist [line] is a bit high, you can see my navel (participant pulls up trousers)'* (*Table 4-29*). The act of adjusting the trouser waistline in this instance demonstrated that the participant was using the garment to mask a portion of the body she was not comfortable revealing.

The bodice block is customarily the first pattern to be generated from body measurements. It would be the basis for styled garments and would not normally appear in a clothing retail environment. Therefore, it was reasoned that although a block was a suitable garment to observe landmark and identifying measurement error through the pattern geometry and fit, the bodice garment itself was not what the participant would normally choose to wear and could seem unattractive to them. This would explain some of the comments regarding the aesthetics of the garment. A styled garment - a blouse, for example - could have been used and this might have had more a pleasing aesthetic for the participant. However, styled garments have additional style lines and ease and this would have made it difficult to determine if the landmarking had been correct. This is what this research was focused on and, therefore, the bodice was the garment fit for purpose for this research.

4.9.4 Issues with bust shaping and circumference

The observer visually checked the bust girth and found the toile appeared tight around the bust girth. They suggested that this could have occurred because of a change in the participants lingerie (different bras can offer different breast support) from the day of being scanned to the day of the toile fitting or insufficient ease values incorporated into the pattern which is not unexpected as this research found that pattern construction guidance is more is more appropriate for a younger person who displays a standard body morphology as discussed in 2.4.1.

Interestingly every participant also offered negative feedback concerning the bust region of the toile. Overall comments were that the bust circumference was too tight or darts too long for all of the toiles made using both unmodified and modified scan measurements (*Table 4-29, Table 4-31* and *Table 4-33*). This was not unexpected as there had been no modification to any of the participants bust landmarks when the scans underwent the SLVM and CDVELA processes. However, what was unexpected was the fact that the bust girth had changed in value from the unmodified bust girth to the modified. The changes in bust girth were small as shown in *Figure 4-87* below but it is curious that these changes had occurred in the first instance to a measurement that has had no modification.

During the period of experiential learning (*Table 3-2*: Activity 8) the landmarks of the leg were found to be linked as any modification of the ankle landmark produced a small change in knee positioning. This research reflected on this and therefore deduced that the bust girth measurement and its accompanying landmarks must also be linked to other landmarks across the torso producing these small changes in girth measurement. This research concluded that this was another area which needed future research as linked landmarks means that the scanner technician has reduced control concerning landmark modification as moving particular landmarks can impact on the positioning of others.

subject code	subject shape	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	The change in bust girth
C65	triangle	119.26	119.27	0.00
I55	bottom hourglass	98.59	98.44	0.15
F70	rectangle	116.39	116.63	-0.24

Figure 4-87 The change in bust girth measurement for scans which have had no bust landmark modification

The fact that participants feedback included comments concerning the bust region is interesting as according to the t-test results this was the area of the body which when correlated with older age is more likely to give an erroneous landmark position which will need modification. Which again prompts further research into appropriate bust landmarking for an older female demographic aged 55+.

4.9.5 Participants preferred toile

Bodice one received more negative comments than bodice two. At the end of each fitting, the participants were asked which bodice they felt was a better fit. All participants chose bodice two as the bodice that in their opinion had better fit. Bodice two was developed using measurements from modified scans which had been had been through both the SLVM and CDVELA processes. Therefore this response provided a clear indication that the SLVM and CDVELA processes were necessary if using a 3D bodyscanner for pattern construction. This is because unmodified scan measurements could contain errors, which could significantly impact on the geometry of the pattern, as seen in *Figure 4-76*, and these errors could then impact on garment fit (*Figure 4-21*). This research therefore concluded that the fitting process and pro forma (used in Objective [5]) enabled validation by the participant of both the SLVM and CDVELA processes. The research also found that both the SLVM and CDVELA processes directly contributed to improving garment for women aged 55+ which was the purpose of Objective [5] (*Figure 3-1, Table 3-2*: Activity 31).

5 The Findings and Discussion - Part Two

5.1 Introduction to the structure of the chapter

This is the Findings and Discussion – Part Two chapter. This chapter focuses on the findings of the retailer measurement guidance survey and the case study of the High street retailer, which were undertaken as part of Objective [4]. Although Objective [4] is listed before Objective [5] (which was discussed in the previous chapter) the decision to place it within its own chapter was taken for two reasons. The first being that Objectives [1]-[3] and [5] focus on the development of the visual aid, the CDVELA process and the testing of this process via pattern development and a fitting sessions. The Objectives have the participant as their primary focus and the above processes are used in a bespoke context.

Objective [4] determines and scrutinises the clothing industry's requirements and application of anthropometric practice, 3D bodyscanning technology and the SLVM and CDVELA processes as the industry operates within a mass production context. Therefore, it seemed appropriate to separate it from the other Objectives and place it in its own chapter. This decision was also taken as the research spanned six years, and although the research was undertaken on a part-time basis, the work is nevertheless lengthy. Therefore, to aid understanding and navigation of the work this portion of the research is separated into two chapters.

This chapter will first present and discuss the findings of the retailer measurement guidance survey (Activity 21) and follow on with the findings and discussion of the case study (Activities 22, 23, 24,25 and 26). The data gathered using both methodologies is predominantly qualitative as discussed in section 3.17 of the methodology chapter. However the findings of both methodologies will be presented using visuals, tables, charts and selected pieces of text which will be referenced against the appendices (Appendix K, Appendix Land Appendix AA) which contains details of how the qualitative data was reduced and its content coded and analysed).

5.2 The findings and discussion of the measurement guidance survey (Activity 21)

The survey of retailer measurement guidance undertaken for Objective [4] (*Figure 3-1, Table 3-2*: Activity 21) provided insight into how retailers use measurement guidance information online to enable customers to determine their body size, to compare it to that of their body or garment size charts and then choose an appropriate garment size from the sizes they offer as a part of their distance selling side of the business.

This research concluded that providing this guidance implied that retailers trusted in the customer's ability (using their proprioceptive knowledge) to translate this guidance into practice. Indeed, this research found that retailers relied on the customer understanding of their own body morphology to be able to undertake self-measurement using retailer provided written and visual guidance.

The importance of the measurement guidance cannot be underestimated as this facility can determine whether a customer will make a purchase. With this in mind, the results of the retailer measurement guidance survey were surprising in that this research discovered that very often the guidance - mainly in the form of imagery - was meagre, inappropriate or, for some retailers, non-existent (the content of which will be discussed in section 5.2.1 below). This research maintains this to be a new finding as a search for comparable studies concerning retailer measurement guidance development and practice (for the literature review) was revealed as is very scant.

5.2.1 Unrealistic or aspirational images

This research collated 57 retailers (Appendix K) which catered for women aged 55+ via the questionnaire (3.9.8, *Table 4-18*) and added additional retailers using the following criteria which is also illustrated in *Figure 3-22*:

- Size charts did not contain exceptionally small sizes such as a size 4 or 6
- The models used to promote the garments looked mature
- The garments were styled or accessorised in a more classic manner

This research found through analysing the content of clothing retailer's online guidance (see Appendix K and Appendix L) that clothing retailers often used unrealistic or aspirational images as part of its measurement guidance as shown in *Figure 5-1* below.

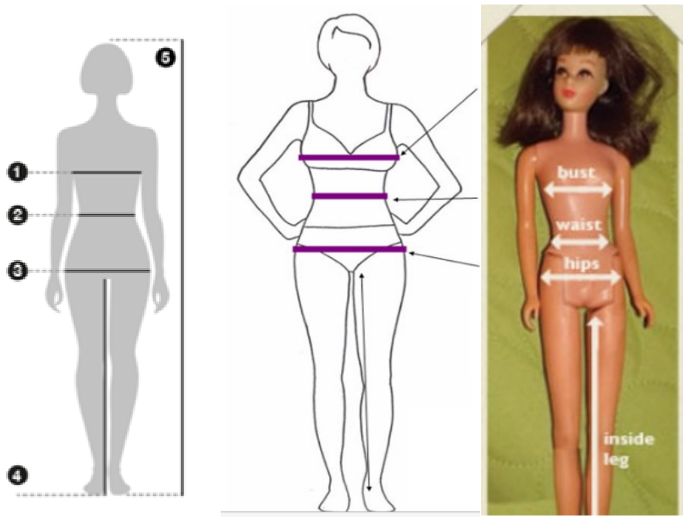


Figure 5-1 Examples of unrealistic images used for measurement guidance by clothing retailers aimed at women aged 55+

The images above are inappropriate in that they display figures that were slender and have a clearly defined waist position akin to a more youthful physique. The use of such images reinforced Twigg's (2015) earlier findings, which indicated that retailers, although catering for an older demographic, did not wish to be clearly perceived as doing so. This research maintains that the use of these images (particularly the image of the doll) also runs the risk of reinforcing negative body image as it is highly unlikely that these images will match the body size and shape of the mature customer.

Remarkably, of the 57 companies surveyed (Appendix K), only two companies provided images that were more representative of their target customer. Those companies were found to be Roman and Wallis (Appendix K, Appendix L) as shown in *Figure 5-2* below.

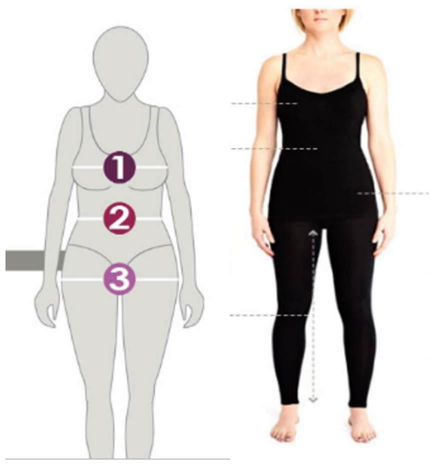


Figure 5-2 Figure used by clothing retailers showing a more representative body shape of a mature women

These images (*Figure 5-2*) depict a fuller body shape. The image on the left, though schematic, did show a lower bust point and a slightly lower head angle, which indicated the shoulders might be rolled more forward and symptomatic of age-related changes. The image on the right is a photograph of an older woman, which an older customer could relate to.

5.2.2 Content analysis of the visual measurement guidance

This research already had established, via a review of pattern construction literature (Appendix C), that anthropometric guidance uses both images and annotation as a means of communicating the practice. With this in mind, this research found, through analysis of the content of the measurement guidance (Appendix L) that of the 57 companies surveyed only 38 provided both images and written guidance as shown in *Table 5-1, and* Appendix K.

CONTENT	**Provided images and annotation**	**Annotation only**	**No visuals or annotation**
Amount of companies	38	16	3

Table 5-1 Content of the measurement guidance provided by clothing retailers

This research also established that 16 companies gave information in a written format (Appendix K), which was not ideal as the inclusion of images provides additional clarity when combined with written details. This research also found that 3 retailers, although having an online presences and products to sell, gave no measurement guidance, which was remarkable as their competitors do. This research maintains this as a new finding – there is nothing comparable in the knowledge base - and one which clothing retailers should consider when developing their web-presence.

5.2.3 Content analysis of the written measurement guidance

This research established that retailers mainly required customers to take bust waist and hip (Appendix K) measurements (using a flexible tape measure) to determine their garment size code. Other measurements such as inside leg featured in some retailer's guidance but this was not universal. This was an interesting as the findings from the questionnaire (Activity 13) indicated that the participants also find garment length (either too long or short) an issue as illustrated in *Figure 4-24,* and they perceived errors in garment length to be one of the factors which made a garment fit poorly and feel uncomfortable to wear (4.4.6).

The structure of the written guidance was such that the instructions for bust, waist and hip were mainly placed at the side of the image with either a code or the name of the body attribute plus a definition of how to take the measurement as shown in *Figure 5-3* below. This aligns somewhat with the structure of body measurement guidance for pattern development (Appendix C) which may have been the initial source.

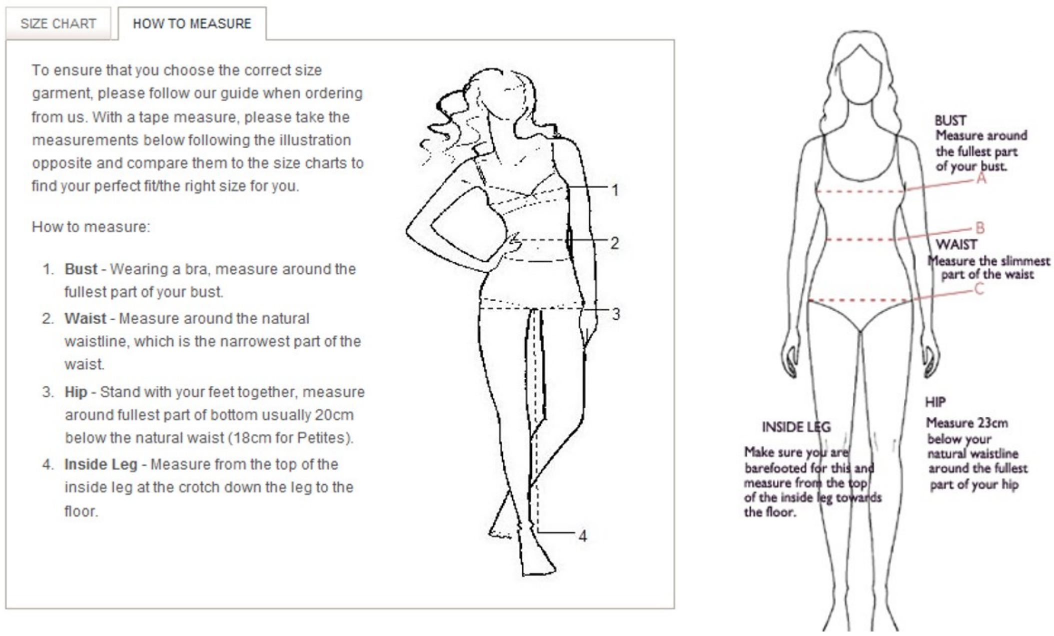


Figure 5-3 How body attributes were signposted by clothing retailers

5.2.4 The definitions of bust and waist measurements used by clothing retailers

Content analysis of the terms used to define the measurement positions for bust, waist and hips (as shown in Appendix K) revealed that clothing retailers used descriptive terms of the body surface terrain alongside commonly known body attribute terms for landmark terms. For example, when measuring the bust an anthropometric practitioner will locate the point of greatest prominence (this maybe the nipple), the armpit, and the scapula. These will be marked and a tape measure drawn horizontally over these points. Clothing retailers undertake the same process, but referred to the point of greatest prominence as the fullest part of the bust, the armpits as underneath the arms and the scapula as the shoulder blades. They then advised that customers place a tape measure over these areas horizontally and levelly to achieve a bust measurement reading.

> '*Directly under-arm place tape measure at fullest part of the bust and across shoulder blades'* (Appendix L).

The word 'fullest' was the most commonly used term applied to the bust prominence, and analysis revealed that 'fullest' was used 47 times in 44 different clothing retailers' measurement descriptions for the bust girth measurement (see Appendix L).

Locating a waist position is difficult as there are no obvious tissue or bone protrusions, as with the bust or the hips. Therefore the research found that retailers used the term 'natural waistline' to indicate the site of the waist on customers, '*making sure the tape is not too tight and is level measure around your natural waistline'* (Appendix L). Using the term 'natural waistline' could leave the customer scope to decide where their waist is on their body. A count of the term 'natural waistline' indicated that it appeared 34 times in 42 different clothing retailers' measurement descriptions for the waist girth (Appendix L).

In summary, this research found that clothing retailers who cater for a mature female demographic typically do provide measurement guidance online as a means to helping their customers choose the right size garment. They will provide images and written guidance but the images used are vague or inappropriate for this age group. Retailers appeared to trust the customer understanding and ability to undertake the guidance accurately. Retailers used common terms to name body landmarks and measurement descriptions that made the descriptions easy to understand. However, it was unfortunate that the retailer did not go further to provide the means to allow customers to measurement the depths between bust, waist, and hips, and to allow this information to be uploaded and sent back to them.

This extra information would allow the customer more engagement with the product development process, which according to Hu (2013) improved customer satisfaction with the product. If the data were utilised correctly in the pattern it could improve both garment fit and the proffered measurement guidance.

What this research found remarkable was that the clothing retailers' measurement guidance was based on the body and not on garments. This was encouraging as when compared to the earlier findings of Wren and Gill (2010) wherein clothing practitioners were more focused on garment measurements and appeared to be less concerned about the body measurements of their customers.

5.3 Case study – establishing retailers/manufacturers requirements when applying landmarking definitions to current industry protocols Objective [4]

5.3.1 <u>The presentation of the findings for the case study</u>

Other than the fact that SizeUK was undertaken to collect data from a broad adult age range for clothing purposes, there was no information within the knowledge base which provided insight of how a Large UK High Street clothing manufacturer and retailer would apply the technology within its business to improve garment fit for women aged 55+. Without this information, it is difficult to determine how best to develop and apply body scanning technology for the improvement of garment fit for a mature demographic within an industrial environment. This research had already developed a series of processes to engage participants (*Figure 3-1*, *Table 3-2*: Activities 13 and 14) in the scanning process and evaluate scan viability, correct landmark error (the SLVM, *Figure 3-1*, *Table 3-2*: Activity 17) and assess possible cause of this error through a series of classification systems and analysis of the changes in measurements (*Figure 3-1*, *Table 3-2*: Activity 18). These processes required validation within a business context as ultimately this research had developed them for use by a clothing practitioner working within the clothing industry (1.1).

Therefore, this research undertook a case study of a large High Street to establish their understanding of the technology and how they would applied it within their business using the processes already developed by this research. This information was vital to develop a means of integrating bodyscanning into an already existing product development model using the skills set of the clothing practitioner.

All verbal and written correspondence was analysed, tabulated and coded as explained and outlined in the methodology chapter within section 3.17.12, and as illustrated in

Appendix AA. Themes were identified and colour coded see *Table 5-2* for each themes colour. These colour codes were used throughout within charts and tables making it easier to see how frequently themes appeared throughout the case study.

Pink – Marketing	Yellow – Scanner utilisation	Green – Aims and achievements	Blue – Time and cost	Purple – Engagement with the customer	Red - Company research	Grey - Positive about technology	Cobalt – Fit	Olive - Privacy	Teal - Logistics	Navy – seeking approval	Dk grey – scanner accuracy	Brown - communication	Forest - Standardisation

Table 5-2 Colour coded themes from the case study

The data gathered during the case study was qualitative and therefore was rich in themes, as can be seen in the transcribed and coded data (Appendix AA), and the colour coded figure directly above (*Table 5-2*). However, this research will discuss in detail only the main themes related to the understanding and usage of 3D bodyscanning technology by the company it studied.

5.3.2 Theme one - communication

Unsurprisingly the theme of communication appeared regularly in the correspondence between the university and the company (Appendix AA). The term and associated statements or words were coloured coded brown. These (brown) colour coded terms or statements were counted by this research (as shown in Appendix AA). The count revealed it to be the most frequent theme as shown in *Figure 5-4* (the brown line), and the pattern of this theme demonstrated that it appeared consistently throughout the case study period. A count of each coded statement/term that either directly or indirectly referred to communication revealed the theme appeared 67 times over the course of the case study period (*Figure 5-5*).

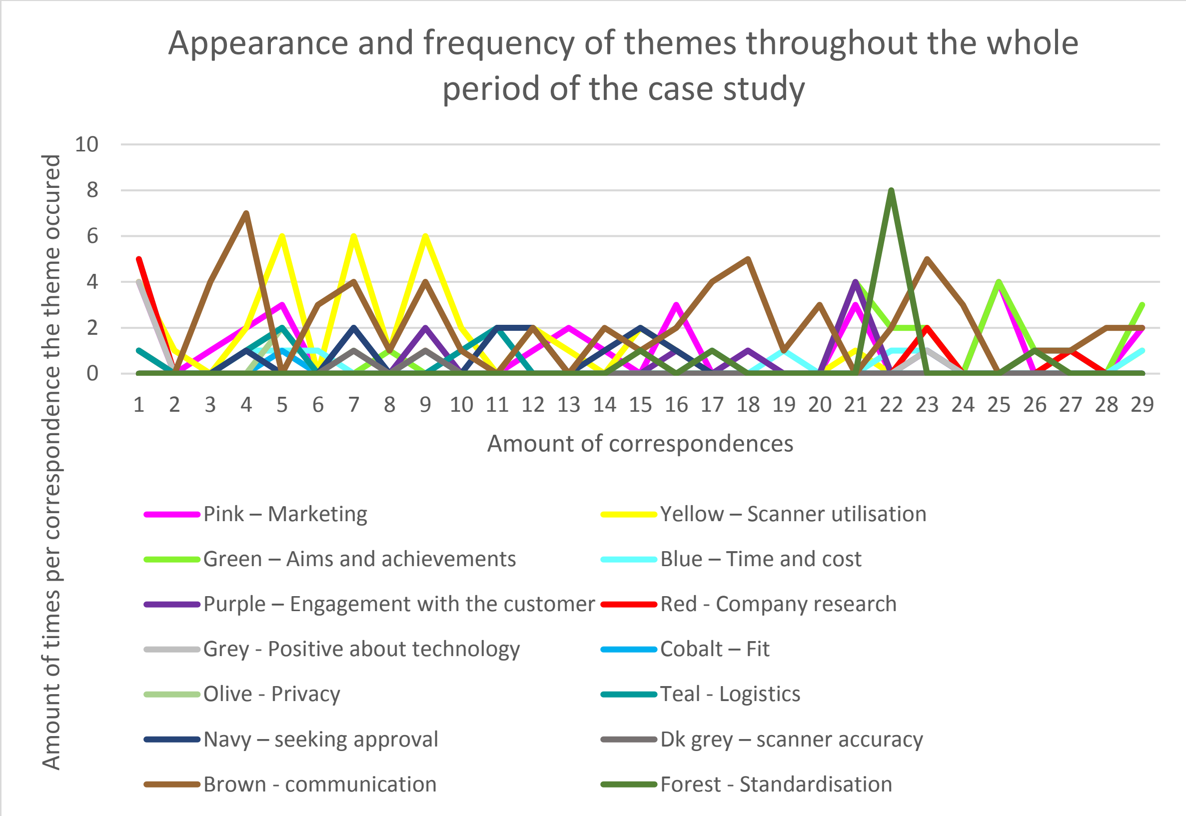


Figure 5-4 Flow and frequency of each theme throughout the case study period

This research found that communication was important as the company was dealing with an external academic institution whose terms, processes, aims and timescales different from their own. They were also exploring a technology they did not own. Consequently, as the company's the marketing team and later the garment technology department discovered more about the scanners potential, beyond that of a promotional tool, they were keen to understand its applications further as their company did not own a scanner and therefore it was not available to use regularly within their business.

The company did not know how to operate the scanner, as they needed to be given demonstrations on several occasions when they visited the University. Although they wanted to hire the scanner for an up and coming event the implicit understanding would be that academic staff would set up and operate the scanner, would write specific MEPs which be defined by the company and would deal with scan evaluation and data cleansing at the end of the event. This finding supports this research's earlier findings from Objective [1], which indicated that currently clothing practitioners do not have the skill set to operate and manipulate the 3D bodyscanning technology, as they have no regular access to the technology. This knowledge further supported the need for this thesis and this research to be undertaken.

Terms such as those inserted in *Table 5-3* below were found in the correspondence and linked to the theme of communication (indeed, they appear throughout the transcriptions, Appendix AA). Interestingly, they were all verbs that were used by the company, demonstrating that they were inquisitive about scanner technology, had many questions regarding it application, and required the university to confirm its suitability for combination with Metail as a virtual fit tool.

Common words associated with the main theme of communication			
discuss	know	investigate	work-out
ask	confirm	question	talk
guide	find	show	requested
arrange	report	comment	explain

Table 5-3 words from the transcriptions associated with communication

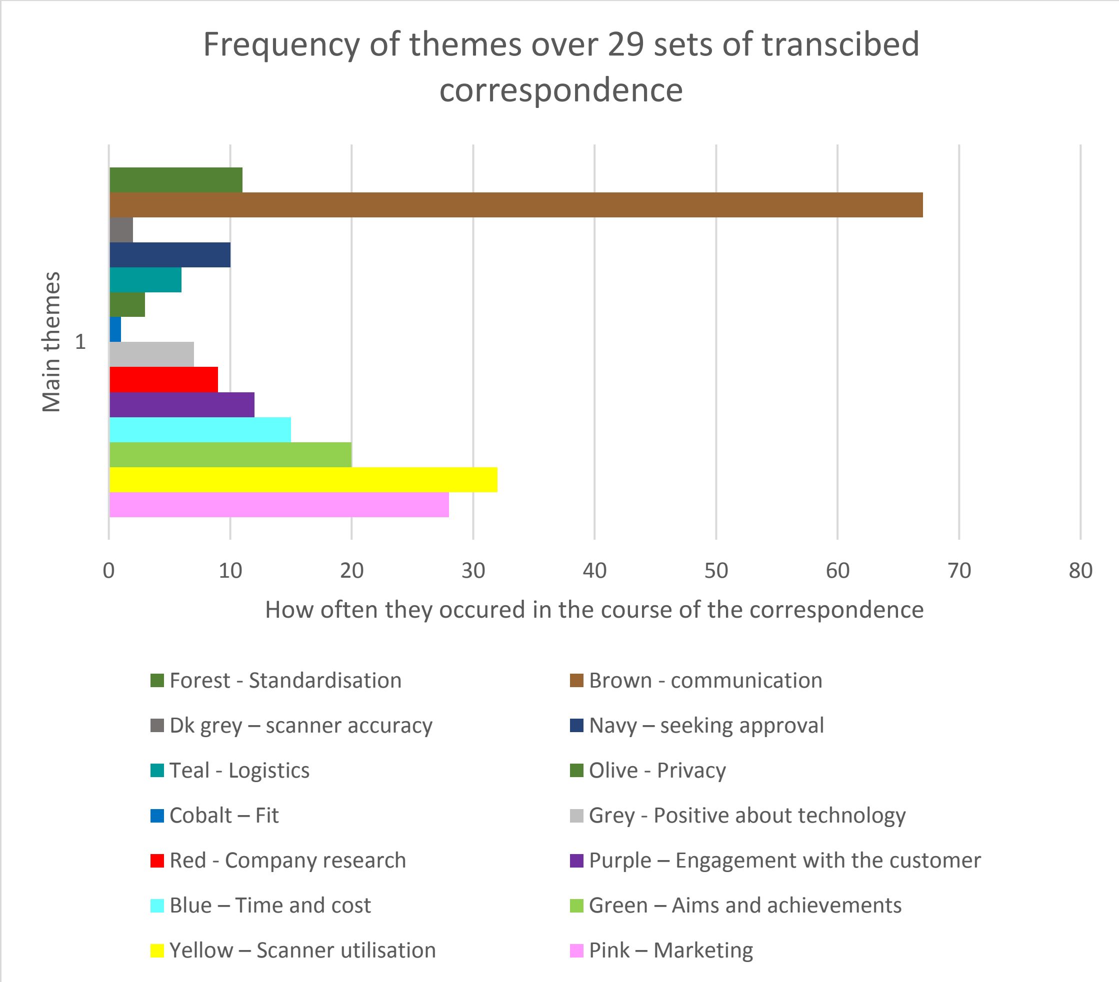


Figure 5-5 Frequency of main themes established from the case study data

Communication between the company and university was mainly in the form of emails with some face- to-face meetings prior to the event as evidenced in Appendix AA. Communicating over a distance meant that both parties use different types of media to convey and share information. Video, Dropbox, email, charts, screen shots, tables (Appendix AA, 35.1.3; 35.1.15; 35.1.18; 35.1.20) were used thereby demonstrating that both parties were open at the beginning to sharing the information. However, partway through the case study and prior to the event, the company decided to include the garment technology department in the email discussion.

The garment technologists were informed by the scanning team that the scanner could provide them with participant body shape information, which could be used to in their block development. In return for this, the garment technology department provided current size chart information and details of how to calculate a garment size using a combination of body measurements (Appendix AA; 35.1.16).

The garment technology department were actively involved during the face-to-face meetings and discussed developing a questionnaire to collect data on participant's clothing size/fit requirements and shopping preferences, which this research was able to help with having already developed a questionnaire for its own survey (3.9.8). However, the garment technology department were slow to respond to emails, and would fail to send information on to the scanning team as this statement from the marketing department to the scan team confirms, '*Thanks you for getting back to me. I've just chased for the bra sizes, I'm sorry this hasn't been sent, I thought you had everything*' (Appendix AA; 35.1.16: para 15).

As more personnel from the company became involved in the email discussions communications grew more complex as the company and scan team were unsure of whom they were supposed to be liaising with. This did cause frustration for the company's head of research and marketing which this statement illustrates clearly *'[C]ould you please respond to my emails regarding the bra conversion chart. Are you around today to talk about the event?'* (Appendix AA, 35.1.16: para 35).

5.3.3 Theme two - utilisation of the 3D bodyscanner

The theme of utilisation also appeared regularly in the correspondence between the university and the company (Appendix AA). The term and associated statements or words were coloured coded yellow (*Table 5-2*). These (yellow) colour coded terms or statements were counted by this research (as shown in Appendix AA). The count revealed utilisation to be the second most frequent theme as illustrated in *Figure 5-5*. For the purposes of this research, this was of primary importance as it provided information on what the company knew about the scanner and how they wished to apply it within their business.

There were also lesser frequent themes such as scanner accuracy, scanner research and a positivity to scanning technology which are included in the next few paragraphs as the context in which they appeared also related to scanner utilisation (Appendix AA).

A count of each yellow coded statement (which either directly or indirectly referenced scanner utilisation) revealed that the scanner utilisation theme appeared 32 times throughout the transcriptions as illustrated in *Figure 5-5*, and, that the pattern of this theme occurred more frequently at the beginning of the case study (as illustrated in *Figure 5-4* the yellow line) when the discussion was focused on the acquisition and utilisation of the scanner for the company event.

Analysis of content of the correspondence (via open coding) by this research within Appendix AA indicated that the marketing team and the garment technology department appeared to understand that the scanner could measure individuals and provide body size measurements. They also appeared to have had previous knowledge of bodyscanning technology, which indicated a level of research had taken place by themselves. This is illustrated well in the following statement taken from Appendix AA; 35.1.8: para 12

> ‘[I] *think we need to discuss on Tuesday […] the need for wearing flesh coloured underwear in the scan’*

This statement showed awareness of how underwear choices could impact on image quality, something that might not be apparent unless researched beforehand.

This company, according to Sizemic, had been part of the core group of retailers involved in the SizeUK survey, and although this was not discussed directly during the case study this research deduced that the company’s involvement in previous non-contact anthropometric surveys could have imparted information of bodyscanning technology techniques making them more knowledgeable about the technology and perhaps seeing its potential in their business.

This research established that the company’s main focus at the beginning of the correspondence was to link the numerical data from the bodyscanner with a virtual fit technology called ‘Metail’. Metail, as previously discussed (2.11.7), is a virtual try-on technology that allows customers to input key body dimensions within its database, allowing Metail to recommend particular size codes for a variety of different garments. The company had recently purchased Metail and they were very positive about its application, believing as the following statement demonstrates it would be a solution to improving fit for their customer.

'*Metail, […] records the customer's height, bust, waist and hips measurements and recommends the right size'* (Appendix AA; 35.1.1: para 3).

This research acknowledges that linking bodyscanning technologies to other applications is not new. Studies such as Bougourd (2015); Gribbin, 2014; Lee *et al*, 2012, and King (2014) (2.11.4) have all discussed how the clothing industry is exploring emerging virtual fit technologies in an effort to make the scanners outputs more meaningful and applicable within a business context.

Companies, such as Alvanon, supply the clothing industry with mannequins that have used scan data to develop more realistic body shapes with some success. The case study company had dealt with Alvanon previously. Indeed, they had used some of Alvanon's material to demonstrate their needs to the scanner team previously (Appendix AA; 35.1.20). These details led this research to conclude that as the company had seen other companies linking scanning data to other applications successfully they could have perceived that linking the scanner data with the virtual fit tool would pose no issue. The following statement from the marketing department confirmed confidence and positivity, both about bodyscanning and virtual fit technology, and demonstrated their belief that linking the two systems together would be a straightforward process:

'*Visitors to the stand would be able to have their body scanned and then we'd help them input the data into our virtual fitting room which is run in partnership with a company called Metail, this records the customer's height, bust, waist and hips measurements and recommends the right size'* (Appendix AA; 35.1.1: para 3).

This research established - through content analysis of the correspondence - that both the marketing and garment technology departments were clear on what measurements they wanted from the bodyscanner – bust, waist and hips - as these measurements were needed for Metail to work effectively. The scanner team required that the company gave a definition of these measurements and landmarks so a MEP could be written. It became apparent that the company wanted to use a very restrictive definition for the waist and the hips and they wanted the scanner to calculate a bra size - '*is it possible to get a reading* *so we can tell customers their bra size?'* Appendix AA; 35.1.7: para 2) – which is garment and not body dimension.

The waist and lower hip girths were defined as being 41cm and 61cm down from the nape of the neck consecutively (Appendix AA; 35.1.10: para 20 notes). These measurements are more akin to garment and not body measurements. Wren and Gill's (2010) earlier publication (Appendix B) concerning the usage of body size to develop garment blocks found that clothing practitioners saw body measurements as less important and less used in their practice. This research concurred with this finding and, in addition, revealed the company perceived the bust; waist and hips garment measurement definitions to be equivalent to the anatomical landmark definitions used for these body areas. This is at odds with the measurement guidance placed on their website which asked customers to measure their body and define their bust and waist measurements using the terms 'fullest part of the bust' and 'natural waistline' (Appendix L).

The company's actions indicate a lack of understanding concerning the details of the technology and how it may be applied with in a clothing context. This finding confirms the necessity for this research in that currently clothing practitioners don't have regular access to the technology and therefore do not have the skill set to understand its potential or how to apply it within their business effectively (1.1*, Figure 3-1, Table 3-2*: Activity 2).

Wren *et al* (2014) had already established in its survey that waist definitions such as those, which allow a tolerance of 2 – 4cm, were not always appropriate for a mature woman's body morphology (4.7.4). Therefore, this research was aware that such restrictive definitions could prove unsuitable. The university scan team therefore developed a MEP with the restrictive measurement definitions as directed by the company but also an alternative MEP that used a waist definition similar to that of the SizeUS survey (which uses the small of the back with a 2.5cm tolerance) as a contingency should any issues arise.

The scan team also worked with the company to utilise the company's bra size calculation into a chart so the bust and under bust measurements provided by the scanner could be used to give a bra size code (Appendix AA; 35.1.18). The company's marketing team at this point saw the development of the bra conversion chart as highly important and their emails suggested they were eager to get this aspect of the event completed (Appendix AA; 35.1.18: para 42). They further realised that Metail required a bra size and not bust measurement information, as was first discussed in the initial communication (5.3.2), *'[For] the Metail recommendation tool the person needs to enter their […] bra size'* (Appendix AA; 35.1.7: para 14).

At this point, it is noteworthy to state that the company's marketing team felt it was not sufficient enough to ask the participant their bra size. This is because they believed that half the participants they would encounter would be wearing an incorrect bra size. The following statement confirmed this: *'[T]here are stats out there saying that over 50% of women are wearing the wrong size bra.'* (Appendix AA; 35.1.7: para 14). From this statement, it could be interpreted that the company perceived the scanner and the bra conversion chart to be more accurate than the information provided by the participant, which again shows a confidence in both the bodyscanner and the Metail technology.

As an aside, the findings of the questionnaire (as evidenced in Appendix AE: 748, and illustrated in *Figure 4-24*) and already revealed that women have issues with garments not fitting correctly around the bust region. The t-test results indicated that bust landmarking was more prone to landmarking error when correlated with older age as illustrated in *Table 4-26*, and in addition, the toile fitting and pro forma feedback confirmed that the bust region was the area most identified by the participants as manifesting poor fit. This is something the company would not have been aware of but which this research can now make evident so future use of the scanner for bust measurement can be more closely scrutinised using both the SLVM and CDVELA processes.

Returning now to the discussion of the company's use of the Metail technology. Although the Metail technology was in the early stages of its implementation within the company, the company assured the scanning team that it would be launched online prior to the event (Appendix AA; 35.1.4: para 10). The company aimed to use Metail on its website and this would allow customers to input their measurements (bra size included) to find out what size garment they should be purchasing. Customers would be required to measure themselves using the typical on-line guidance shown in Appendix K. As noted earlier in this research, this implied that the company trusted its customers to be able to take their own body measurements and that they knew their bra size. This is interesting, as the head of research at the company had already stated (see above) that they expected over 50% of participants to not know their correct bra size at the event.

This research concluded that the company appeared to have more confidence in the ability of the technology (the bodyscanner and the Metail virtual fit tool) to determine body dimension and garment size than that of the customer. However, this research has proposed that both bodyscanning technology and participants' proprioception knowledge to locate and validate anatomical landmark placement can lead to greater measurement accuracy and, hence, greater sizing accuracy. Therefore, this research would argue that customer knowledge is currently undervalued and underutilised by the clothing industry.

The company were confident that their instructions regarding the customised MEP for the bodyscanner and the use of the Metail technology would work. Statements showing such optimism are as follows:

> '*[T]hey will get a completely accurate read of their vital statistics (bra size, weight, height, waist and hips)'*
>
> *'[T]hese can then be inputted into our "check my size" tool, so each consumer can be 100% confident that they're ordering the right size'* (Appendix AA; 35.1.19: para 20).

These statements further reinforced that there is confusion between garment and body size, in that the bra size is classed as a vital statistic – a body measurement - when it is, in fact, a garment size. This underpinned this research's finding that the company had problems differentiating between a body dimension and a garment dimensions.

Over the 3 day scanning event there were problems with the company's waist definition and usage of the bra calculation chart. The issues arose when the scanners readings of bra size and waist were input in the Metail technology and participants complained that the garment sizes they were being offered were incorrect.

Individuals from the company's marketing department complained to the scan team that the scanner was providing incorrect waist and bust measurements and the scanning team reverted to the alternative MEP that had been created as a contingency. However, there were still issues with waist and bust body dimensions as this statement in an email from one of the scanning team confirmed:

> '*I did explain that their definition of 41cm down from the CB neck was a garment and not body measurement and suggested we revert to the [alternative MEP]. They agreed but some of the waist measurements still seemed to be erroneous according to the customers and* [Company Name]*. They also have their own garment tech manually measuring for bra size as they say the scanner measurements are giving the incorrect measurements for bra size.'* (Appendix AA; 35.1.28: para 1).

At this point, it became evident that the company were questioning the accuracy of the measurements provided by the bodyscanner and not the information provided by the Metail technology. The company instructed their own staff to begin taking manual bust measurements and, on occasion, waist measurements. This was done in a private cubical so this research cannot comment on the measurement definitions that were used or how they took the measurements. The company continued with this process for any scanner derived bra size calculation they thought erroneous. This change of plan by the company again reinforces the issues with the bodyscanner providing accurate bust measurements.

5.3.4 Theme three - marketing

The theme of marketing also appeared regularly in the correspondence between the university and the company (Appendix AA). The term and associated statements or words were coloured coded pink (*Table 5-2*). These (pink) colour coded terms or statements were counted by this research (as shown in Appendix AA). The count revealed marketing to be the third most frequent theme (*Figure 5-5*) and it appeared in the correspondence 28 times over the period of the case study. *Figure 5-4*: pink line illustrates that the marketing theme appeared both at the beginning and at the end of the case study correspondence. Less frequent themes such as customer engagement, privacy and aims and achievements were also referred to within this section as they were mentioned within the same context as marketing.

The marketing department asserted that using 3D bodyscanning and virtual fit technologies would present their company as a business that was focused on ensuring garments would fit the customers perfectly. Indeed, they referred to both technologies as '*The perfect fit tool'* (Appendix AA; 35.1.19: para 26).

They also explained that the scanner would play a part in brand positioning and customer perception when they stated, '*The body scanner and "check my fit" tool are all part of the overall positioning of* [Company Name] *as the perfect fit'* (Appendix AA; 35.1.19: para 6). The aim of the marketing department was that aligning themselves with 'new technologies' such as Metail and the 3D bodyscanner would increase sales, as the following statement suggested: '[*M]aximising sales and generating new customers is key'* (Appendix AA; 35.1.19: para 26).

This research found that when the marketing department were appraised of the scanning process and presented with the scan image their responses were less positive concerning the scan image. They felt the scan image was not aspirational enough and asked whether it could be removed from the printout completely or if participants could have their body dimensions recorded on a separate sheet of paper (Appendix AA; 35.1.14). An additional document was developed for this purpose (Appendix AA; 35.1.14). This is noteworthy as it aligns with the findings of Lee *et al* (2011) and Domina *et al* (2007) whose work highlighted that scan images can be uncomfortable for participants to view. This research was not surprised by marketing department's view of the scan image as it had already established that its measurement guidance used unrealistic and aspirational images for its body measurement guidance as illustrated by one of the images within *Figure 5-1*.

The company's marketing department also wanted to use a scan image on the scanning area to promote the bodyscanner at the event. The following statement, however, showed they were particular about the type of scan image:

> 'We'd *like to show an example of the body scan image on the front of the body scan area. But we don't want to have any of the gridlines behind it and we'd like to show a nice body shape'* (Appendix AA; 35.1.11: para 2).

This was further discussed in face-to-face meetings and the company confirmed it wanted an image of a 'slim' individual. With reference to the above quote, it is foreseeable that the marketing department would request an image of this type as Twigg's (2015) earlier work confirmed that retailers would try to avoid being seen as explicitly catering for an older demographic even if they do (2.10.2).

Having a 'nice body shape' and removing the scan image from the printout indicated that the company felt their customer may be encouraged to be scanned if they could see a pleasing scan image on the outside of the scanning area but that they could be upset if their own scan image was markedly different which again aligns with the work of Lee *et al* (2011).

As previously outlined by this research in section 2.9.3, the scan image is not an aspiration image. The individual is minimally clothed and stood in the anatomical posture as illustrated in Appendix N, which is designed to capture the skin surface and not present the body's aspects in an aesthetically pleasing manner.

One year after the company scanning event academics from the Psychology Department at MMU (Grogan *el al*, 2015) interviewed participants from the event and confirmed indeed that some women were concerned about the scan image they were provided with. Therefore, the company's marketing department were perceptive in anticipating this response. However, their action could have also contributed to this a negative response to personal scan images by providing a scan image (on the outside of the scanning area) which was not typical of the demographic they were hoping to attract.

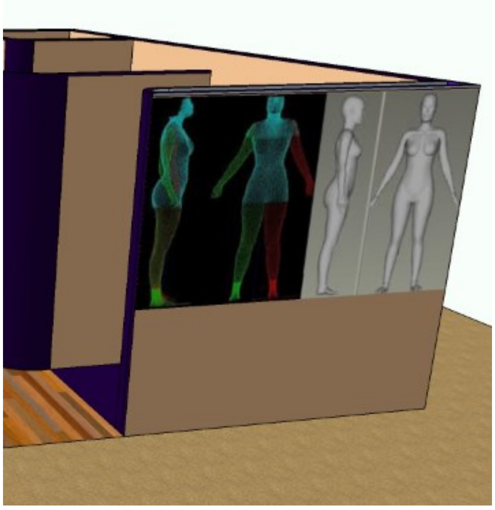


Figure 5-6 the body shape image the company preferred to use to market the scanner for the event

Following the event, the company's marketing department asked the scan team to process the 225 scans of women aged 18-84 with were captured at the event. This was the commencement of Activities 24 and 25 for Objective [4] (*Figure 3-1* and *Table 3-2*). The scan team began the SLVM process as detailed previously in this research (3.11.2).

The company performed their own analysis of the Metail technology by comparing the size recommended by Metail against the size the participant recorded that they wore within the company questionnaire provided at the event. The company found (after the scans had been validated by the SLVM process) that Metail had predicted the correct size code for 97 participants and one size code out for 61 participants. Eighteen scans did not have all the information on them to calculate garment size and were eliminated by the SLVM process, and 23 participants found that were offered a garment size that was more than one size over or under what they normally purchased. These results demonstrate that virtual fit technology when combined with 3D bodyscanning technology require further research as the margin of error when predicting garment size codes is high and will result in dissatisfaction with garment fit for mature women.

With regard to the 23 scans which were found via the SLVM process to have too many errors to be useful. The company noted that these 23 scans that had produced issues when linked to the Metail technology. However, they did not comment whether any of these participants had been manually measured for bust or waist by their garment technologist at the event. These scans were sent back to the scan team for further analysis (using the CDVELA process) with this communication:

> '*The batch we want to dig deeper into are the 23 that were more than one size out thinking are that those who are one size out are explainable because they've probably just put on a few pounds or lost a few without being conscious of it - or they're trying to fool themselves that they're still a bit smaller than they are!!* (Appendix AA; 35.1.21: para 12).

The response above indicated that the company believed the customer was responsible for the garment size error where previously they had thought the scanner was giving erroneous measurements. They were interested in exploring how such errors occurred and as they had purchased the Metail technology were naturally keen to ensure these errors were not as a result of the Metail technology itself. However, it should be noted that at no point over the case study did the company indicate any loss of faith with the Metail technology.

The 23 scans were put through the CDVELA process to determine if there was any measurement error (such as the scanner had placed the waist directly on the under bust measurement which when modified could be done so in cm increments until the correct waist circumference and position was achieved) and to establish a cause, such as an extended abdomen region (Appendix AA; 35.1.22: 7). This provided an opportunity to apply the CDVELA as a diagnostic tool and determine how its findings could be used in the company's report. The company were keen to receive the findings:

> '[*R]eally looking forward to seeing what your analysis of the scans tells us […]* (Appendix AA; 35.1.21: para 21).

The CDVELA process revealed that most of the older sample were rectangles as they had gained excess fat deposition around the abdomen area thereby making the waist less distinct, something which this research had found within its own sample as shown in *Figure 4-38*.

The company were given the results of the CDVELA but they did not indicate in writing if the results had helped them understand why those 23 scans had issues. Their understanding of the results was confirmed in a face-to-face meeting, and the company commented that age related body shape change could impact on what customer perceives their size to be and that this could have affected the accuracy of Metail as a size prediction tool. The CDVELA's results received no negative feedback and therefore this research reasoned that the company were satisfied with its results, which helped validate the process (Figure 3-1, Table 3-2: Activity 26).

The main role of the scan team at this point was to categorise body shapes and to provide statistical information of average body dimensions listed in Appendix AA; 35.1.20: para 77-87. This was done after SLVM and CDVELA processes. The sample was separated into age clusters and each body dimension was compared by age, as this research had done previously. Similarly, Lee et al's (2007) female body shape classification method (Appendix S) was also used to categorise the body shapes and each shape category was also compared by age cluster. This information was presented to the marketing department during a face-to-face interview at the university.

The final stage of the company's marketing strategy included a report using both the scan and questionnaire data it had gathered from the event and data from a larger questionnaire that had been gathered by the company nationally (Appendix AA; 35.1.24: para 11). This larger scale questionnaire was mainly focused on gathering information on how customers engaged with sizing systems and what they understood to be the average size in the UK.

The scan team was not involved in the data gathering, its reduction or analysis of the questionnaire. The report was titled "The Body Census" and the company wanted to use this along with a radio interview using well-known UK female celebrity whose age was aligned with their target demographic. The female celebrity acted as a spokesperson to promote the company brand and to discuss with an academic from the university the findings of the report.

The company was keen to show that they were actively involved with university and were using new technologies, such as the bodyscanner and Metail, to illustrate to the customer that they were a brand who invested in research to better understand their customer.

Therefore, it could be determined that the company saw the bodyscanner as a means of promoting their brand rather than a means of developing better fitting garments. This was deduced as nothing further was asked of the scan team regarding how to apply scan data to company sizing or block developments, which prompted pattern development and toile fitting for Objective [5] whose findings have been outlined in section 4.9 of the previous chapter.

5.4 The theoretical framework and this theses contribution to knowledge (within the clear boxes)

The conceptual model assembling different approaches to anthropometric measurement and depicting their relational links

- The conceptual model was developed to compare and clarify the different approaches to anthropometric measurement using terminology that would be familiar to clothing practitioners, thereby making each process more understandable and therefore accessible to both existing clothing practitioners and new entrants (students) to the clothing industry.
- The conceptual model highlighted that both manual and non-contact anthropometric processes have been combined and that this is possible at a particular stage of the process. It is this stage when participant interaction with the process can take place.

The adaption of non-contact anthropometric practice for mature women

- A visual aid was developed to allow participants to use their proprioceptive knowledge of their body and to interact with the non-contact anthropometric process whilst still maintaining a private measurement environment. This visual aid can be used and adapted for difficult to locate anatomical landmarks.

Quantifying anatomical landmark error

- This thesis identified a calculation to determine landmark error and enable quantitative testing of the null hypothesis using a t-test.
- Using the SLVM process and the t-test this thesis discovered that the 3D bodyscanner is more prone to landmarking error of the bust and crotch points for women aged 55+.

A process to portray the entire sample and assess the probable cause of scan/landmarking error

- The development of the CDVELA process enabled categorisation of the entire sample using body shape calculation, BMI, age and posture. The CDVELA process portrayed the entire sample using descriptive statistics.

- The collation of each category allowed cross checking whereby scan or landmark error of a particular body area could be correlated with age, body shape or BMI thereby establishing probable cause.

Selecting suitable bodice pattern construction methods for a mature woman's body morphology. Combining a predefined pattern method with scan measurements for bodice block development

- Beazley and Bond's, (2003) was found to be the most appropriate method to draft a bodice block for women aged 55+. This is because its list of measurement's contained the side neck point to bust prominence as this was identified as an area prone to age-related change and landmarking error when using non-contact anthropometric methods. This measurement ensured the bodice accommodated a lower bust point so the bust was amply covered.
- Using the definitions closest to that of the chosen pattern construction method a new bodice MEP was developed.

Tools and recommendations for the clothing industry

- A garment fit pro forma was developed which targets regions of the garment prone to fitting error for women aged 55+. The pro forma prompts the participant to evaluate the fit of the garment and not their body size and shape thereby speeding up the fit process.
- This thesis provided recommendations concerning retailers' measurement guidance. The recommendations are that depth as well and girth measurements be collected especially between the key areas of side neck to bust point, bust point to waist, waist to crotch point and crotch point to the floor. These depth measurements can provide more accurately fitting garment in terms of appropriately positioned style lines and suppression areas.

6 Conclusion

6.1 Introduction to the conclusion

Over the course of 6 years, this research has established gaps in the knowledge and contributed new knowledge, processes and tools, which contribute to the current knowledge bases of the following:

- The evolution of the clothing practitioner's skillset to effectively apply new and emerging technologies within the clothing business
- Manual, semi-automatic and non-contact anthropometric practice
- Non-contact anthropometric practice and proprioception for landmarking
- Older age and erroneous landmarks
- The evaluation of scan data
- Bodyscanning as a marketing tool
- Bodyscanning and virtual fit technologies
- Pattern development methods using scan data
- The garment fitting process for mature women aged 55+

The new knowledge, processes and tool have been developed to benefit the following stakeholders:

- Clothing product developers and marketers
- Clothing academics (teaching, research and enterprise)
- Fashion students

Details of how the new knowledge contributes to the existing knowledge base and how it may be applied by the above stakeholders will be expanded throughout this chapter.

6.1.1 The clothing practitioner's skillset

This research established through Objective [1] (1.3.1) that 3D bodyscanning is currently more understood and utilised by academic researchers whose disciplines are that of computer science and statistics. This means their proffered solutions are extrinsic to the skill set of a clothing practitioner whose normal task do not require in depth knowledge of computer manipulation and programming or inferential statistic calculation. This research found via Objective [5] (1.3.1) that industry view 3D bodyscanning technology as a means to providing body measurement which can be combined with other technologies to improve sales. Using the skill set gained by 18 years within the clothing industry this research explored 3D bodyscanning technology in terms of how it is configured and how it operates. The outputs from this resulted in a Scanner hardware and Software Overview and a Survey of Landmarking Methods (Activities 8, 9, 10; section 4.2). These outputs were developed in a configuration (an Excel spreadsheet) which is familiar to the above stakeholders using terminology that is explained within this thesis. These outputs (see Appendix H and can be used by those working in both industry and education as a means of familiarising themselves with how the technology works (the configuration of the hardware and software), which provides useful and much needed information for the purchasing and application of the technology within an industrial or educational environment.

The research contributes new knowledge to the areas of 3D bodyscanning technology comprehension and adoption by clothing practitioners. Outputs from Objective [1] aim to enable clothing practitioners to become more familiar and adept at using 3D bodyscanning technology, as body measurement is the first step in the clothing product development process, and the speed and privacy this technology provides makes it ideal for measuring a mature female demographic.

6.1.2 Manual, semi-automatic and non-contact anthropometric practice

The research determined through Objective [2] (1.3.1) that non-contact anthropometric practice has been developed and benchmarked using manual anthropometric practice. This is something, which is not explicit within the current academic knowledge base nor is it made clear in bodyscanner literature. This research reviewed previous manual anthropometric surveys literature, which revealed detailed guidance on the equipment to use, landmarking and measurement practice and documentation and analysis of the results. It then collated and reviewed information on semi-automatic and non-contact anthropometric surveys that provided the first output of Objective [2] the Anthropometric Surveys Overview (Activity 11, 4.1.1, Appendix A). This output combined with the outputs from Objective [1] informed the development of the second output for Objective [2], the conceptual model (*Figure 3-1, Table 3-2*: Activity 12). This model is novel in that it maps the three different approaches to anthropometric measurement, demonstrating how they are comparable and how they contrast and showing relational links, particularly at the early stages of the model (*Figure 4-16*). This has not be undertaken by any comparable research previously and so its development and realisation is a new contribution to the knowledge base concerning anthropometric practice.

The outputs from Objective [2] are targeted mainly at clothing and anthropometric academics and their students who are more familiar with manual measurement but wish to become more skilled in non-contact anthropometric measurement. The conceptual model illustrates the stages of each process and allows either the academic or student to modify these processes if they saw fit. An example of this was the conceptual model was used by this research to understand where the visual aid could be implemented within the process.

6.1.3 Participant engagement with the 3D bodyscanning process

This research has established within Objective [3] that anatomical landmarking for women aged 55+ using non-contact approaches to body measurement can be prone to error. Error can occur in areas such as waist, bust and crotch point.

This research gathered and illustrated information concerning novel methods of landmarking using 3D bodyscanning technology for body types which are not considered a standard size and shape for Objective [1] (see output in Appendix M). This research also found these methods and their implementation to be extrinsic to the skill set of a clothing practitioner and therefore difficult for a practitioner to recreate of apply within their own discipline. For that reason this research, noting that it is common practice for anthropometric surveys to include a questionnaire developed a tool, which could be placed within a survey format. The tool was termed the visual aid.

The tool was novel in that no previously comparable study has attempted to combine participant proprioceptive knowledge with non-contact landmarking methods to improve the accuracy of landmark positioning for clothing development. The tool and the accompanying questionnaire (Appendix J) were the first output from Objective [3] (*Figure 3-1, Table 3-2*: Activities 13 and 14).

The waist was identified as important for the 55+ demographic as the knowledge base indicated age-related body shape changes make its appearance less discernible and for clothing purposes an area for contention regarding its definition. The definitions chosen allowed the waist to be placed a different intervals between the under bust and mid hip and these were easily represented in pictorial form. Participants engaged with the visual aid and its results confirmed that waist landmarking was incorrect for some participants and allowed for waist position modification.

The tool was novel, and was developed using the skill sets of a clothing practitioner with 18 years of industry experience and therefore was generated for clothing professionals working both in industry and academia who wish to improve accuracy within anatomical landmarking for clothing development. The tool was specifically designed for women aged 55+ who may find scan images distressing or who display a non-standard body morphology. However the tool can be easily changed and for different demographics and genders.

This research finds this tool contributes to the knowledge base surrounding non-contact anthropometric practice for clothing purposes.

6.1.4 A process to evaluate and categorising scan data

The SLVM process facilitated scan viability (Appendix P) and this research's set of t-test's demonstrated which landmarks when correlated with age had a high probability of error (*Figure 3-1, Table 3-2*: Activities 17 and 19). This research determined how to extrapolate a value from unmodified and modified scans quantitative data which would facilitate inferential statistical testing. This calculation (illustrated in *Figure 4-50*) is novel, is the second output within Objective [3], and contributes to the knowledge base relating to landmarking error estimation and landmark positioning. The calculation is simple and can be undertaken by clothing professionals (both within industry and academia) and students alike. The calculation can be applied to any landmark of the body.

This research developed a process for categorising scans and cross checking landmark error against the categories of age, BMI and body shape (*Figure 3-1*, *Table 3-2*: Activity 18). This process was output 3 of Objective [3] and was termed the CDVELA process (as illustrated in Appendix R). The process was developed using the skill set of a clothing practitioner with 18 years of industry experience and as a result is specially developed for easy adoption by professional clothing practitioners who work in both industry and academia.

The process was designed for women of all ages but can easily be used for men without any adaption. The CDVELA process has currently been used in a bespoke setting but with greater usage has the potential to build a database of information which could predict landmark error based on the factors of body shape, age and BMI and with more time and development recommend an alternative landmark definition. This process is new and contributes to the knowledge base related to age-related body shape change and gerontology and anatomical landmarking.

6.1.5 Age-related morphological change and issues with anthropometric and pattern construction practice/guidance

This research found through critical analysis of the existing knowledge base from disparate disciplines revealed that women aged 55+ experienced age-related body morphology changes that occur mainly in the torso region. The literature indicated the changes to be gradual and reflected in body size, shape and posture, to a point whereby a participant's body size, shape and posture no longer aligned with what is considered the standard. Examination of anthropometric and pattern construction guidance visuals indicated that the guidance is based on a standard body morphology that is slim, displays an upright posture and a clearly discernible waist as illustrated within Appendix C.

With this information in mind the research deduced that welling fitting patterns using said guidance would be problematic for woman age 55+ as the methods (which includes the landmark definitions, the measurements taken and the pattern drafting instructions) did not explicitly accommodate a changed body morphology. Therefore, after a review of many pattern construction texts this research found the Beazley and Bond (2003) method to be more suitable as its instruction accommodates a large breast and low bust point. This research is the first of its kind to explicitly explore a pattern method, which aligns with a changed body morphology.

This research also determined that scan measurement and pattern measurement were not always comparable, something that is not explicitly outlined in any research, which combines, pattern construction and bodyscanning data, nor is it stated in any bodyscanning literature. Therefore, this finding is new. With this in mind, this research sought to use and modify existing measurement definitions within the TC² software database and align them with that of Beazley and Bonds (2003) pattern construction guidance. This resulted in the first output of Objective [5] (*Figure 3-1, Table 3-2*: Activity 27) which resulted in the TC² and Beazley and Bond (2003) measurement definition table which can be viewed in Appendix U. The table clarifies the pattern methods measurement definition and then selects an equivalent measurement from the large list of body measurements offered by TC². TC² measurement definitions are not published in this way, which indicates a gap in the knowledge. Therefore discerning and listing comparable measurement definitions in an effort to utilise bodyscanning quantitative data within the pattern is new and contributes to the knowledge areas of pattern construction for older women and pattern development using bodyscanning data.

The method of comparing and concluding measurement definitions is outlined within the research (3.14.4) and would benefit those new to scanning technology and in particular the TC² scanner. The output was developed for a clothing practitioner (either expert or novice) and would enable them to draft a bodice block pattern for women from any age group. The method of finding measurement definitions for both pattern guidance and within the TC² MEP editor facilitate would remain the same for any type of garment that makes it easy to apply.

Using the pattern development and toile fitting as a test instrument to validate the SLVM and CDVELA processes (*Figure 3-1*, *Table 3-2*: Activity 28) is also novel way for a clothing practitioner to examine the accuracy of the measurement positions and measurement values from scans they have modified. Practice such as this is new as a search of the knowledge base - focused on bodyscanning for clothing application - found that information concerning landmark evaluation was scant to non-existent and certainly did not use pattern construction to check landmark viability.

This second output from Objective [5] was configured first as a spreadsheet of bodice block pattern measurements using unmodified and modified scan data (Appendix V). The second part of the output used pattern geometry (over laying pattern pieces that were constructed using unmodified and modified scan data) and assessing the differences in their geometry. This could be how they varied in length as discussed in section 4.8.8 or shape as in the case of the armhole as discussed in section 4.8.7. In addition, these changes in pattern geometry for each participant were compared against their CDVELA notes (Appendix R) to help determine the cause of pattern geometry change. Moreover, patterns developed from younger women's scan data were compared women from the older sample who share similar heights. This approach showed how the geometry of the body and the subsequent pattern changes due to ageing and flags area of the pattern where that change is most apparent. It also demonstrated that landmarking error also occurs on younger women's scans (predominantly around the armscye region) if they are categorised as having a high scoring BMI or their body shape reflects a rectangle or bottom hourglass shape.

This research confirmed that using the context of the pattern showed the impact of erroneous and modified landmarking in terms of the change of pattern geometry, something which had not be explored in current literature focused on utilising bodyscanning data for pattern construction for non-standard body morphologies, and is therefore new.

This research determine that the process of using patterns to check landmark modification coupled with the information contained within the CDVELA spreadsheets provided enhanced guidance for academic pattern practitioners wishing the utilise scan data within their teaching practice using a bespoke approach. Therefore the primary stakeholder who would benefit from this output would be clothing practitioners who currently make bespoke or made-to-measure garments and who wish to utilise 3D bodyscanning measurement data within a pattern and garment fitting context.

6.1.6 The toile fit pro forma

Documentation, which supports the garment fitting process, is commonplace within the clothing industry. However this research determined that previous studies centred on the garment fitting process did so from the perspective of the clothing practitioner and therefore information of participant sensory and visual feedback regarding the garment fit is within a garment fit meeting is very scarce indicating a gap in the knowledge base. This research has addressed this paucity of information by developing its last output of

Objective [5] (*Figure 3-1*, *Table 3-2*: Activity 29) which is the fit pro forma as illustrated in Appendix Y.

The pro forma was developed by a clothing practitioner with 18 years of pattern and garment fitting experience plus 7 years in academia, and is therefore developed do be easily adopted by clothing professionals and fit models. The fit pro forma is novel in that it prompted the participant to assess specific garment attributes and not their body morphology in a systematic manner. In addition, it facilitated sensory garment fit feedback from the participant wearing the garment when common industry practice dictates that the observer only gives garment fit feedback in a fit session (Wren and Gill, 2010) which reinforces its originality and its contribution to the knowledge base concerning garment fit practice.

This pro forma was developed for women aged 55+. However, with adaptation by a pattern/garment technologist, it can be used for any age or any garment and would be particularly useful to online retailers who wish to find out specifically why a garment was returned and not purchased as this output targets specific attributes of the garment where fit is an issue allowing the retailer to reassess the product's particular attributes in light of this information.

6.1.7 Industries requirements of 3D bodyscanning technology

This research began Objective [4] by determining how retailers utilise anthropometric guidance with in their online business model (*Figure 3-1* The process map of the development of the research question and the methodologies used by this thesis *Table 3-2*: Activity 21). It started by developing a structure to identify and collate and analyse measurement guidance from pertinent retailers (those who the participants shopped with and retailers whose attributes aligned with search criteria developed by this research and discussed in section 3.17.2). To target comparable components of the guidance, as a means of reducing it, and analysing elements of its content details of which can be viewed in Appendix L. Appendix K contains the survey of retailer's measurement guidance output. The comparable components referred to above were as follows: the type of imagery used, the layout and/or coding of the guidance, the clarity of written instruction, the names/definitions of each key measurement and the amount of measurements required.

The retailer's survey guidance is novel and valuable to retailers as collation and analysis of each component of the guidance clearly indicated a need to explore more appropriate imagery to demonstrate how to measure the body morphology of mature women, something which is not explicitly covered in the current knowledge base. The findings also indicated landmark definitions used terms such as the 'natural waistline'. Terms such as this implied that the customer could decide on where they felt their waist was, which supported the use of the visual aid developed by this research.

6.1.8 The case study's contribution to the knowledge base

This research undertook the case study (*Figure 3-1*, *Table 3-2*: Activities 22, 23, 24 and 25) to determine what a large UK High Street retailer (here after referred to as the company) would require from 3D bodyscanning technology and how it would use this technology within their business. The findings of this would satisfy Objective [4] as well as operating and validating the CDVELA process within an industry context.

Analysis of literature concerned with the application of 3D bodyscanning informed this research that although academics are seeking to apply the technology to the clothing product development process, it main usage was that of a survey tool from which average body measurements could be statistically calculated and used for size charts, mannequin development and customer size prediction as discussed in section 2.11. The case study's findings somewhat supported this in that the company required the scanner to be used to collect body measurements for statistical analysis so it could calculate averages of its customers bust, waist and hips. It also combined scanning technology with that of virtual try-on technology in an effort to increase its sales. This demonstrated that the company trusted the accuracy of the technology for body measurement location and extraction over that of conventional manual measurement approaches. However this research went on to establish during the duration of the case study that the company did not fully comprehend the possibilities and limitations of the scanner and had no desire to learn how to operate the system, found the scan imagery to be inappropriate to show to its customers, lost trust in the scanner's ability to give accurate bust and waist measurements, and showed confusion between garment and body measurements. On a positive note, this research found that the company regarded the outputs of the scanner as valuable and went on to use the results within a major marketing campaign featured both in the national press and on radio. The company also placed faith within the scan team and the CDVELA process, which used in this context, provided explanations of why measurements were erroneous and also categorised the sample into body shapes that were used as part of a marketing campaign. The case study allowed the CDVELA to be applied in an industry context and validated its outcomes by using the outcomes as a means of marketing their product and demonstrating the flexibility of the process. Unfortunately, the CDVELA outcomes did not inform the case study company's clothing product development at that time but this was because the company felt the sample frame was too small.

The outputs from the case study were valuable insight into how a large High Street perceived 3D bodyscanning technology and how it applies it within their business. Such information is not published as the clothing industry, much like the bodyscanning industry is protective of its processes and artefacts, seeing them as a part of their competitive advantage. Therefore, the case study contributes new knowledge to the knowledge base concerning clothing industry practice and the clothing industry's perceptions of 3D scanning and virtual try-on technologies. This new knowledge it aimed at clothing academics who seek to develop 3D bodyscanning applications for the clothing industry. The findings are limited to a UK clothing retailer and would be enriched by further by research of international retailers.

6.1.9 The methodological approach used by this research

The final output of this research was the methodological design it created to produce the above outputs and findings. This research was undertaken by a clothing practitioner with 18 years' worth of industry experience and 7 years of academic experience and so this determined that the outputs needed to be easily comprehended and utilised by clothing practitioners both in industry and in academia.

Therefore, the design incorporated the following methods:

Surveys

Creating tools (the visual aid and the fit pro forma) using, CAD, Excel, Visio

Anthropometric practice

Categorising and segmenting participants (age, BMI, height, body shape)

Descriptive and inferential statistics

Observation (field notes, photographs, meeting minutes, emails, artefacts)

Pattern construction (manual and Gerber)

A fit meeting

The above methodologies would be familiar to professional clothing practitioners working in either industry or in academic therefore making this research design easy to adopt and modify for further clothing related research.

6.2 The limitations of the research

This research had limitations, which will be discussed in the following sections.

6.2.1 Sample size

The first limitation concerned the size of the samples used. There were factors that restricted the sample size of each age cluster within this research. The size of the 55+ demography sample was governed by individuals being willing to participate and this research's ethical code dictates that it never coerce an individual into participation. With regard to this research's mature sample size, the sample was larger than other previous comparable studies that have sought to gather primary data using 3D bodyscanning technology for clothing development.

With regard to the younger sample sizes. The size of 55+ demographic sample and the quantity of scans held within the university database at the time of recruitment also governed the total sample sizes from the other younger age clusters. Both of these clusters were representative in that the participants (all of the age clusters) displayed a variety of body sizes, shapes and BMI scores.

6.2.2 Lack of diverse ethnic mix

The majority of the mature sample contained participants whose ethnicity was self-categorised as white. This research acknowledged that the study would have benefitted from a more diverse cultural spread. This research used mixed recruitment strategies to communicate the survey to as many women as possible in a variety of locations. That said, this research was reliant on participant willingness to take part and in this research more participants categorised self-categorised as white expressed an interest in taking part.

6.2.3 UK study

The survey of retailer measurement guidance used online sites for the UK and the case study of a UK based business. The outputs from these methods can be thought of as limited to the UK. This research acknowledges data collection using international clothing retailer may have given a different result.

6.3 Recommendations for further study

During the course of this research, it became clear that particular pattern construction guidance and body scanner measurement definitions differ, even though the definitions used by this research were, according to TC², designed for clothing development.

If a clothing practitioner wanted to use scan data they would also need be familiar with the process of writing a MEP, which more closely reflect the definitions used by the selected pattern guidance.

This research recommends that further study into the development of new MEPs for specific pattern construction guidance would be necessary to enable the greater adoption of bodyscanning technology by pattern technicians.

During the course of this research, it became clear that younger women who display non-standard body morphologies, particularly those with high BMI scores and non-discernible waists shapes could experience incorrect landmark placement during scanning and measurement extraction, albeit to a lesser extent than those over age 55+.

This research recommends using the tools/processes developed by this study - the Visual aid, the CDVELA and the fit pro-forma - to explore how to improve garment fit for this demographic.

This research highlighted that to improve garment fit for women aged 55+ further engagement by the clothing practitioner with the 3D bodyscanning technology and the participant is achievable using the processes and pro-forma documents created by this research. This could bring a positive outcome to the process of being scanned and the resulting amended garment.

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9 Appendix A

9.1 Table of Anthropometric surveys

Country	Year	Demographic and socio-demographic infomation gathered	System used	Body undertaking survey	Amount measured or scanned	Number of measure-ments taken & if landmark…	Contact	Survey Published	Purpose of survey	Ref
Australia	2002	Adult women ranging from 18-100 years of ages with the average at 49 years. (Henneberg, Ulijaszek, 2009)	Manual measurements only. All measurers were trained in standard Martin's anthropometric technique and in taking garment-relevant measurements according to the International Standards Organisation document 8559 (1989) (Henneberg & Veitch, 2005).	The National Body Size and Shape Survey of Australia was conducted in 2002.	1266	More than 60 dimensions were measured, including weight, stature, length, and width of body segments, circumferences of trunk, head and limbs, and triceps, subscapular, and abdominal skinfolds (Henneberg, Ulijaszek, 2009).	Daisy Veitch, SHARP Dummies Pty Ltd., 102 Gloucester Avenue, Belair 5052, Australia E-mail: daisy@sharpdummies.com.au	Survey procedure and some statistics published through Henneberg & Ulijaszek's study on the relationship to BMI and skinfold thickness.	Civilian survey aimed at improvement in apparel sizing standards.	Henneberg, & Ulijaszek, (2009), Henneberg & Veitch (2005)
Bulgaria	2007	Male and female between the ages of 30-40 years.	Not specified	Bulgarian National Science Fund (TH-1407/04)	5290 (2435 males and 2855 females)		Gergana1973@gmail.co. (G S Nikolova) ytoshev@imbm.bas.bg (Y E Toshev)			
China	2004-2006	children and young adults (aged 4-17)	Lectra's 3D measurement solution *	China National Institute of Standardization (CNIS)	20,000		Jean-Louis Heyd, Lectra's worldwide project manager			

France	2006	5 to 70-year olds, (men, women and children) (IFTH.og, 2006).	Vitus Smart * (IFTH.org, 2006)	Institute Francais du Textile et de l'Habillement (IFTH)	11562	63 standing and 28 sitting measurements, as well as the regression coefficients that can be useful for anticipating the measurements (via,fr, 2007). 55 automatic measurments and 10 manual (Kirchdörfer, & Rupp, 2006).	communication@ifth.org e-mail: mensuration@ifth.org	Apart from a few comparative statistics the survey results are not published and data is available to interested companies for a price (IFTH.org, 2006)	Civilian anthropometric survey to provide French body sizes to improve garment fit. This information will allow apparel making companies to overhaul their garment sizing and grading databases (IFTH.org, 2006)	IFTH.org, (2006), Via.fr, (2007), (Kirchdörfer, & Rupp, 2006)
Germany	1999	Female 14-80+	Vitus Pro *	Bra Project	1500	84 automatic measurements taken by the scanner and one (height) taken manually (Kirchdörfer, & Rupp, 2006), There were also 2 stances standing 2 sitting (Kirchdörfer, & Rupp, 2006).	Mrs. Elfriede Kirchdörfer Mr. Martin Rupp Bekleidungsphysiologisches Institut Hohenstein Schloss Hohenstein 74357 Boennigheim Germany		Anthropometric data for bra development	(Kirchdörfer, & Rupp, 2006)
Germany	2001	Female 18-70	Vitus Smart *	E-Tailor	500	8 automatic and 2 manual measurements taken in both sitting and standing positions (Kirchdörfer, & Rupp, 2006)	as above		Anthropometric data for made to measure	(Kirchdörfer, & Rupp, 2006)

Germany	2002	Female 50-80	Vitus Smart *	Project Elderly Women	1300	84 automatic measurements taken by the scanner and one (height) taken manually (Kirchdörfer, & Rupp, 2006), There were also 2 stances standing 2 sitting (Kirchdörfer, & Rupp, 2006).	as above			(Kirchdörfer, & Rupp, 2006)
Germany	2008	Female 18-80 socio-demographic data such as gender and age were gathered for further analysis.	Human Solutions*	**Size Germany** Hohenstein Institute, Human Solutions and other partners from the clothing and automotive industry.	13362 in three standing positions and one sitting position.	44 body dimensions, such as hip and chest circumference, as well as 53 body dimensions for the purposes of technical ergonomics. All body measurement points were informed by the size charts from the Hohenstein Institute.	sizegermany@human-solutions.com contacted Martin Rupp 9/01/10 at the Hohenstein Institute to enquire as to the exact amount and location of measurements taken and if the landmarks were premarked.	Data sets are not available to the public, "the data on the site are shielded from unauthorized access through a multi-layered system that guarantees the security of partner companies' investments." (Hohenstein.de), this information is proprietary and can only be accessed through an internet portal. SizeGermany has not provide a portal address for the general public.	Actual German body size to improve clothing fit and prove ergonomic size information for the automotive industry.	
India	2008	Female and male 18-24	Manual measurements using the ASTM Methods D 6240. 29 measurements for men & 35 for women	Textile Technology Department at IIT Delhi	1000 women and 500 men		deepti@textile.iitd.ernet.in			

Italy	2002	Female and male 18-65	TC2 Landmarks pre marked	CAESAR	800 (also manually measured)	38 measurements some manual	K. Robinette, Air Force Research Laboratory, 2800 Q Street, Bldg 824, Wright–Patterson AFB, OH 45433-7947, USA	Can only be viewed if licence is purchased.	For ergonomic and clothing puirposes	
Japan	2003	Males 20-30 yrs. , Females 21-35 yrs (AIST, 2003)	Hamamatsu Photonics corporation, body line scanner C9036-02 and traditional manual measurements (AIST, 2003)	AIST Research Institute of Human Engineering for Quality Life	49 males, 48 females, landmarks were pre marked. In the report (which is in Japanese) there is a detailed table of landmarks used and their definitions. The report needs a full translation, however 21 landmarks were used (AIST, 2003)	Amount of measurements taken are 94 for females, 90 for males (AIST, 2003).	prpub@m.aist.go.jp for publication enquiries.	Methodology of survey published in Japanese only.	The aim of this project is to generate possible human motions for getting into a car, and to assess the load and comfort during the motions.	
Korea	April 2003 to November 2004	Male and female aged 8-74	Cyberware WB4 *	Korean Agency for Technology and Standards	4934 subjects Subjects measured manually and scanned.		South Korean Research Institute of Standard and Science	Report published regarding statisitcal analysis. This report has not been translated to English. Data set has been used by Han et al, for their 2010 and 2011 studies regarding landmarking for individual torso shapes and the development of landmark algorithms.		

Malaysia	August to December, 2009	TBC (emailed Prof. Merican 11/11/09)	TC]² NX-16 3D body scanner.*	University of Malaya, CRYSTAL research Institute, & University of London	TBC (emailed Prof. Merican 11/11/09)		Prof. Dr. Amir Feisal Merican Email merican@mysize.com.my / merican@um.edu.my			
Mexico	2004	Men and Women	[TC]² *	CONACYT, the National Council of Science and Technology	6,600		Dr Lilia Prado-León of the Ergonomics Research Center at the University of Guadalajara			
Netherlands	1997-2002	Male and female adults 1200	Vitus Pro Landmarks pre marked	CAESAR	1200 (also manually measured)	38 mesurement using manual and semi automatic measurements. Right side only measured.	Hein Daanen, TNO Human Factors, PO Box 23, 3769 ZG Soesterberg, The Netherlands	Hudson, JA and K. M. Robinette, 2003: CAESAR: Summary statistics for the adult population (ages 18-65) of the Netherlands. AFRL-HE-WP-TR-2004-0168. United States Air Force Research Laboratory, Human Effectiveness Directorate Crew System Interface Division		

Sweden	2005	13 to 65+ male and females	Vitus Smart (Hanson et al, 2009)		4,000	Standing and seated positions.			Sizing survey	Kirchdörfer, & Rupp, (2006), Hanson et al, (2009)
Spain	2008	Adult females mixed ages (1) Subjects were asked their age, place of birth, birth place of parents, where they live, dietary information, health and problems with garment fit.	Vitus Smart XXL and Anthroscan Some manual measurements used and subjects pre landmarked. (1) Subjects also had skinfolds on the scapula (shoulder blades), tricipital (anterior aspect of the bicep) and Suprailiac (skin fold on waist line at sides) areas of the body (1),	Institutio de Biomecanica de Valencia (IBV) partnered with Spanish Association of Designers. Starting point www.ibv.org – INDITEX – MANGO – Grupo CORTEFIEL – El Corte Inglés – Carrefour (1)	10000 (1) in three different postures, standard anthropometric posture, anthropometric seated (only 25% measurements taken with this position) and standing with forearm at 90 degrees to body and hand held straight.	15 markers on landmarks. Lanmarks marked were scapula, acromion, C7, illiac crest, medial condyle, trocanter, hip protusion & waist. Hands were scanned separately using polhemus hardware (1).	sandra.alemany@ibv.upv.es ibv@ibv.upv.es • www.ibv.org	Unsure if results published to general public. Basic statistical analysis of anthropometric data: mean, percentiles, standard deviation, correlations, graphs,… • Study of morphotypes. www.ibv.org • PCA and clustering (1D measures). • Basic analysis of the sociodemographic questionnaires. • Correlations anthropometry-sociologic variables. The data goes towards updating the EN 13402 (CEN/TC 248/ WG 10: Size designation system of clothing). (1)	The survey provided anthropometric information for the following area: garment and footwear fit, the true size of the Spanish female population, data for the correct development of manikins for retail outlets (1).	1

Spain	2003	Adolescents Male and female	Manual only Tape, Holtain skin fold calliper, standard beam balance (scales),	AVENA Study. Survey is looking at harmonization of anthropometric measurements for a nutrition survey carried out over 5 cities. Researchers concentrated on measurement accuracies using the calculation of intra and inter-observer errors of measurement.	101 58 boys, 43 girls		Luis A Moreno, PhD, EU Ciencias de la Salud, Universidad de Zaragoza, Avida. Domingo Miral s/n, 50009 Zaragoza, Spain. lmoreno@posta.unizar.es	Survey and results published in an academic paper.	Survey is looking at harmonization of anthropometric measurements for a nutrition survey carried out over 5 cities. Researchers concentrated on measurement accuracies using the calculation of intra and inter-observer errors of measurement(González-Gross et al, 2003).	Alemany (2008), González-Gross et al, (2003)

Spain	2007	Solders male and female	Vitus Smart XXL and Anthroscan Some manual measurements used and subjects pre landmarked. Other scanners used were a 3D head scanner (I-ware), a 3D Foot/hand scanner (I-ware) and a generic 3D handle scanner (Polhemus).	Institutio de Biomecanica de Valencia (IBV)	male 303, female 213, 3 postures standard anthropometric posture, anthropometric seated (only 25% measurements taken with this position) and standing with forearm at 90 degrees to body and hand held straight.	11 markers placed on landmarks, landmarks were not specified. Measure-ment followed NATO standard: STANAG 2177 (Ed2): Methodology for Anthropometric Data	sandra.alemany@ibv.upv.es ibv@ibv.upv.es • www.ibv.org		Uniform fit, workplace ergonomics.	1
Sweden	2008	Females and males aged 18-65	Vitus/Smart D & Scanworx v2.7.2 for whole body in various positions. Manual measurements for hands, feet, head stature. *	Anthropometric survey for product and workplace design.	367, 105 males & 262 females		Lars.hanson@design.ith.se. Tel: 00 46 222 40 66			
Thailand	2009	Adult males and females	[TC]² *	SizeThailand initiative	13,442 (Charoensiriwath, Srichaikul, 2009)		Jean-Louis Heyd, Lectra's worldwide project manager	Charoensiriwath,S., & Srichaikul,P., (2009), *Constructing Thailand's National Anthropometrics Database using 3D Body Scanning Technology* (Online) www.pnclink.org/pnc2009/chinese/Abstract/08-Unfoldinge-Culture/08_UnfoldingeCulture_Abstract_PiyawutSrichaikul.pdf *(accessed June 2011)*	To provide accurate body dimensions for the garment and automotive industry (Boonnoon , 2009). To improve Thailand's sizing standards (nectec.or.th, 2009)	Ping. (2009), nectec.or.th, (2009), Boonnoon , (2009)

UK	2009	boys and girls aged 4 to 17	[TC]² *	Shape GB, sponsored by	6,000		www.shapegb.org or The Project Director, The Shape GB Survey, c/o Select Research Ltd, 42, Calthorpe Road, Edgbaston, Birmingham. B15 1TS.		In order to design children's clothes to ensure the best possible fit retailers need to understand - in detail - the size and shape of boys and girls in different age groups (shapegb, 2010).	

UK	2001	UK adult population, 5,000 female and 5,000 male subjects between the ages of 16 and 85+ (Sizemic.eu, 2009). Volunteers filled in a short questionnaire to provide contact details, age, sex, and ethnic origin Wells et al, (2007).	[TC]² *	SizeUK is a consortium of 16 major UK Clothing Retailers (Sizemic.eu, 2009).	11,000	The software automatically extracts >130 measurements per scan. Measurements used in this survey were manual measurements of weight, height, and head circumference and 3-D of the chest, bust (women only), midupper arm, waist, hips, midthigh, and	Sizemic on (+44) 203 051 2644 or visit the Sizemic website (www.sizemic.eu)	Data sets are not available to the public, is owned by 17 retailers (Sizemic.eu, 2009). Smaller academic publications have published such as Wells et al's (2007) study on BMI compaired to 3 dimensional shape.	To update their size charts, improve garment fit and maximise the percentage of their customers that can fit their clothes (Sizemic.eu, 2009).	Sizemic.eu, (2009), Wells et al, (2007)
USA	2002-2004	U.S. Population	[TC]² *	[TC]² Size USA	11,000		5651 Dillard Dr. Cary, NC 27518 USA Phone: 919.380.2156			
USA	2000	Male and female	Cyberware WB4 Landmarks pre marked	CAESAR	2400 (also manually measured)	38	No name given.	Can only be viewed if licence is purchased	Ergonomic and clothing purposes.	store.sa.org, (2011), *CAESAR The most comprehensive source for body measurement data* (Online) http://store.sae.org/caesar/#3deu *(accessed Jan 2011)*

USA & Canada	April 1998 to early 2000	Male and Female 18-64	Vitronic Vitus Cyberware WB4 Landmarks pre marked	Civilian American and European Surface Anthropometry Resource (CAESAR)	2400 U.S and Canadian and 2000 European civilians		Kathleen Robinette Armstrong Labs 2255 H St AL/CFHD WPAFB, OH 45433-7022 Phone: 937/255-8810 Fax: 937/255-8752	Survey results are not available for free to the general public but can be purchased.	Ergonomic and clothing purposes.	

10 Appendix B

10.1 The author's MSc publication at the Textile Institute Centenary Conference 2010

Paper reference:

Wren, P. and Gill, S. (2010) 'Industry fit practices and the issues that impact on good garment fit' in 100TH TEXTILE INSTITUTE WORLD CONFERENCE, VOL 3, CONFERENCE PROCEEDINGS, Manchester, UK, NOV 02-04, 2010.

Industry fit practices and the issues that impact on good garment fit

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Abstract

Purpose

This research establishes the skills sets and processes of current industry practitioners and the effect this has on the achievement of good garment fit. This is contrasted with established definitions of good garment fit, outlined in current literature, and provides evidence of areas which should be addressed through training.

Methodology

A methodological strategy was developed to collect and analyse data from clothing professionals currently working within the clothing industry. A convenience sample of individuals working within various garment development roles for a variety of market levels were selected. Semi structured interviews were employed to gather data on industry processes and protocols. A fit evaluation tool was developed synthesising Fastfit, a tool that allows practitioners to view moving 360° pictures of garments, and literature definitions of

good garment fit. This tool enabled the collection of observational data on practitioners' skill sets. Both methods were used in the same instance.

Findings

The paper established that although subjects worked at different market levels, their processes were similar and often individual practices within or perceptions of the process impacted directly on the garment fit. Skill set levels also varied within the sample set even between individuals who performed similar roles, which resulted in a variation of knowledge regarding suitable fit. Results indicated that problems with garment fit are cumulative, with issues involving practitioner skills levels and bad practice impacting on garment fit.

It was identified that current academic research, centred on utilising technology for the improvement of garment fit, proffered solutions which were unfamiliar to practitioners, in terms of their skill sets and geared towards technologies not available within their workplaces. This study found that there has been little research focused on the practitioners themselves, their practices, the skills sets they are equipped with and the structures in which they operate.

Originality and recommendations

This paper identifies current industry practices and skills sets to inform academic researchers and educational professionals who utilise technology for the improvement of garment fit. This paper further recommends that the skill set of practitioners be considered when providing academically derived solutions to facilitate ready implementation by the industry. This would also allow the development of a curriculum compatible with the needs of industry but which is able to integrate new ideas, practices and technologies in harmony with existing human resources and practices.

Introduction

Good garment fit is crucial to customer satisfaction as it contributes to both confidence and the comfort of the wear (Alexander *et al*, 2005). Dissatisfaction of fit is one of the most frequently stated problems with garment purchases (Mastamet -Mason *et al,* 2008) in the ready-to-wear sector.

The process of garment development is comprised of a number of stages with garment conception, development, and realisation being accomplished by a number of different practitioners using a variety of processes (Tyler, 2008). Within this process garment fit is influenced by practitioner skills and/or the processes they operate within. As a result many academic studies seek to analyse and provide solutions by concentrating on specific areas of the process, such as sizing and body shape analysis (Loker *et al*, 2005; Ashdown *et al*, 2007a; Ashdown *et al*, 2007b); the integration of pattern development and 3D body scanning technologies (Daanen and Hong, 2008; Chen, 2007); the exploration of accurate ease values for pattern development (Xu & Zhang, 2009; Chen *et al*, 2008); and the garment fitting process (Bye & LaBat, 2005; Ashdown & Mete, 2008). Many of these studies explore new and emerging technologies resulting, at times, in novel methods which require new skills and protocols.

The clothing industry operates as a chain and so solutions need to be holistically developed with an overview of not just the physical processes but of the skill sets within the industry.

This approach may ensure new research solutions that are easily understood and implemented thereby precipitating adoption.

Literature review

Loss of skills

Studies have shown a shortage of technical skills within the UK clothing industry (Winterton & Winterton, 2002; Skillsfast-UK, 2008). Research into the contraction of the UK clothing industry and the effect this has had on skills levels and training suggests that this is due to globalisation (Tyler, 2003; Winterton & Winterton, 2002; Jones & Hayes, 2004). This has resulted in a transfer of skills to remote sites with companies placing their production in countries with lower costs (Tyler, 2003; Winterton & Winterton; 2002; Jones & Hayes, 2004). Tyler's (2003) study, though disputing the 'terminal decline' of the UK clothing industry as a whole, conceded that the area of garment production that has cost as the main motivating factor has all but disappeared from the UK.

DesMarteau's (2000) article discusses the reasons that industry struggles in providing good fit. She suggests that skills levels have been affected because of the popularity of knitted fabrics and simplistic styling, which can lead to the expertise of pattern developers not being challenged and so remaining less advanced. Vouyouka (2007), concurred with this view and suggested a paradigm shift was necessary that would involve training and development for all levels of personnel, thereby providing understanding between departments, which would ultimately result in more innovation and better fitting garments. Both Winterton and Winterton (2002) and Skillsfast-UK (2008) state that industry has accepted the argument for more trained technical personnel. Winterton and Winterton's (2002) survey of clothing businesses revealed companies were highly concerned over skills shortages and how this leads to quality issues. Nevertheless, despite these concerns, companies were reluctant to provide adequate training to remedy this situation (Winterton & Winterton, 2002). As the UK clothing industry is dominated by small businesses they typically have limited resources with which to train staff (Skillsfast-UK, 2008). They instead rely on a trickle down from skilled practitioners who have been trained by larger organisations (Skillsfast-UK, 2008). However, due to industry contraction larger companies are training less new practitioners (Skillsfast-UK, 2008; Winterton & Winterton, 2002). So, without any formal induction practitioners are required to obtain the knowledge whilst they work. Therefore, it is possible that the skill set of the practitioner acts as a further constraint thereby impacting on garment fit. In addition, the clothing industry currently works within tight time constraints brought about by business strategies, such as Fast Fashion, introduced to reduce buying cycle processes and compress lead times to get product to store and satisfy customer demand at its peak (Barnes & Lea-Greenwood, 2006). With many high street retailers adopting such strategies it is unsurprising that the allocation of time for training is not prioritised as practitioners are constrained by tight deadlines.

It has been identified that the clothing industry uses out-of-date body size charts, a practice that is known to affect garment fit (Goldsberry *et al,* 1996; Simmons *et al*, 2004; Ashdown *et al*, 2007a; Workman & Lentz, 2000; Faust *et al*, 2006). Some companies use no body size chart at all. Workman and Lenz's (2000) study found many of the measurements required for determining size are garment measurements, not body measurements. This may be due to companies using bought sample garments to obtain the initial measurements

(Faust *et al*, 2006) and involves a company buying a competitors' garment specifically for the garment's measurements which are used as a basis for developing their own size charts (Frings, 2008, Glock & Kunz, 2005). Companies may, on occasion, disassemble the garment and draft an entire pattern from the disassembled pieces (Frings, 2008; Glock & Kunz, 2005). By copying the competitor's design they are also copying the competitor's fit (Workman & Lentz, 2000), which saves a company time from having to engineer similar fit into a new block.

There are multiple drawbacks to this approach. Clothing textiles are prone to deforming (Orzarda, 2001) and fabric properties play a large part in garment fit due to changes in dimensional stability (Fan *et al*, 2004; Geršak, 2002). With this in mind, measurements from a bought garment sample are therefore difficult to obtain with absolute accuracy. It follows that if a company uses these measurements as the basis of a garment size chart the probability of inaccurate fit is highly likely. As copying garments is not uncommon (Glock & Kunz, 2005), and is taught on some clothing courses and is a component of some pattern-making textbooks (Marcketti & Parsons, 2006), it is hardly surprising that problems of poor fit are so widespread.

Sizing and body measurement

Technology such as 3D body scanning is perceived as the panacea to the problem of sizing (Faust *et al*, 2006). Its advantages are it is quicker, more objective and facilitates more privacy when compared to traditional anthropometric methods (Fan *et al*, 2004; Simmons & Istook, 2003). Prior to 3D body scanning technology, sizing surveys were performed manually and were time consuming and largely inaccurate if not undertaken by a skilled operator (Istook & Hwang, 2000). This is perhaps one of the reasons companies compile their own size charts empirically, adjusting them every few seasons but never really targeting the actual size of person they are catering for (Faust *et al*, 2006). Due to this practice, sizing systems from each company vary, resulting in a lack of standardisation in size codes and categories thereby excluding some customers from their offer due to poor fit (Kinley, 2003).

The UK clothing industry in association with government and academic institutions has funded a large scale survey of the current population in order to ascertain the population's average body size and shape (Sizemic, 2010). Size UK, untaken by Sizemic in conjunction with industry and academic partners, scanned male and female individuals from ages 16-85+ to provide body dimension data (Sizemic, 2010). This indicates the UK clothing industry has recognised the need for current anthropometric data in the development of its size charts.

Access to the Size UK data, however, is limited as it is proprietary and can only be purchased through Sizemic, who will provide the data in limited configurations which are price dependant and the cost of the technology has been proposed as being a barrier to adoption (Aldrich, 2008; Ashdown & Dunne, 2006). So, the results of the survey are not freely available to the industry, and therefore not freely accessible for the development of specific clothing applications by practitioners within the industry. Accordingly, studies have been undertaken by academics to explore how best to utilise 3D body scanning technology in the quest for accurate garment sizing to improve fit. (Loker *et al*, 2005; Ashdown *et al*, 2007b). It is believed that the technology is ideal for this area as it not only provides a comprehensive list of body surface measurements but also supplies information of body shape and cross-sectional views of the subject, whereby body volume can also be calculated (Simmons & Istook, 2003). The clothing industry traditionally uses linier measurements in the development of a garment (Loker *et al*, 2005) and the tools used may be physical measurement devices, measurement commands within a pattern development system (PDS) or tables of measurement values. Drafting patterns or assessing garment fit using 3d scanning technology may seem far removed from current ways of working. Consequently, the industry's current practices, tools and skill sets must be taken into consideration if the data on body shape and volume provided by the 3d scanning technology is to be utilised within the garment development process.

Ease values

3D body scanning technology has also been explored as a tool to assess body/garment relationships through the segmentation of scan images (Loker *et al*, 2005). Loker *et al* (2005) used body scanning technology to compare industry sizing against consumers' actual body dimensions and shape. Their aim was to develop and communicate a variety of statistical and visual analysis methods to describe and address the variety of body shapes and measurements that exist within sizing systems (Loker *et al,* 2005). The study used size-specific analysis of body scan data to provide additional data for the improvement of garment fit (Loker *et al,* 2005). Their methods required partially- and fully-clothed subject scan data which had been segmented at specific anatomical points (body landmarks such as the waist). These segments were overlaid to identify variety in shape and circumference at specific anatomical points and to calculate ease values (ease being the space between the body and the garment). Analysis provided an opportunity to assess the relationship between the body and the garments, something which in industry fit meetings is not ordinarily possible, again perhaps due to limited access to 3D body scanning facilities. This study clearly indicated ease in terms of a visual and a value. However, to implement Loker *et al*'s (2005) methods practitioners would need to acquire new skills to manipulate the scans and calculate ease percentages, which they are not required to do at present. Practitioners would also have to have a good working knowledge of calculating ease in strategic areas of the pattern or garment. This could prove difficult as pattern developers generally use heuristic knowledge to incorporate ease (Kunick, 1984) and so this practice may be extrinsic to their current processes and ways of thinking.

Gill *et al* (2008) acknowledged a lack of existing sources to inform academics and practitioners of functional ease allowances (basic ease requirement related to dynamic movement) which can be contextualised and used in pattern construction. This study involved the creation of a framework for determining garment pattern functional ease and consisted of the exploration of body measurement changes from static to dynamic postures to be recorded to a database format (Gill *et al*, 2008). They found establishing ease values using this method provided practitioners greater objective control over the pattern, thereby reducing the iterative process of assessing garments for fit (Gill *et al*, 2008). Incorporating the methods for measurement and anatomical landmarking however required anthropometric training, knowledge of anatomy, and an up-to-date body measurement size chart, skills and tools which may not currently be used by industry.

The fitting process

Bye and LaBat's (2005) study of the fit process highlighted flawed practice which arose due to conflicts between practitioners whose main concern is either perfecting fit or perfecting design. Their study found a culture of vagueness and a lack of agreement in what constituted good fit (Bye & LaBat, 2005). Ashdown and O'Connell's (2006) study suggested there is a variation in the protocols used to assess fit. Their aim was to assess if concentrated training on fit through various methods could produce the same results between students and experienced practitioners (Ashdown and O'Connell, 2006). Their training incorporated a standard framework, developed by Erwin and Kinchen (1969) which state the elements of line, ease, set, balance and grain need to be in equilibrium with body dimensions to achieve good fit. They recruited clothing students for the study and trained them using various methods for a short period. Practioners and trained students assessed a garment and they judgements were compared. Their findings indicated that post-training judgments on fit were similar between both groups. Training of this nature would be beneficial for the clothing industry in that new entrants are made aware of these elements and how they affect garment fit. They show within the limitations of their study that a considered and standardised training programme can bridge the knowledge gap.

Methodology

Subject selection

A convenience sample of nine individuals was chosen with one of the nine (subject A) selected to pilot the study methods. The number of participants is greater than comparable research and would provide data saturation, suggested to occur with only six interviewees (Guest *et al*, 2006). Subjects were required to have five or more year's industry experience and to have attended garment fit meetings and to have had input in the development of the garment, as they would provide the necessary data for this study (Table 1). All subjects had experience of fitting or commenting on fit for womenswear garments for the High Street.

Subject profiles						
Subject	**Role**	**Years in role**	**Company type & size**	**Market level**	**Garment category**	**Target Demographic**
B	Designer/ Senior Designer	5	Small Supplier	Middle	Menswear formal shirts and trousers	18-45
C	Senior Designer/ Head of Design	15	Small Specialist Retailer	Middle	Womenswear Formal & casual Knitted and woven multi products	45+
D	Garment Technologist	20	Larger Growing Retailer	Value	Womenswear Formalwear, knitted and woven multi product	34+
E	Quality Controller/ Product Developer	15	Medium Sized Supplier / Importer	Value	Womenswear Formal and casual knitted and woven Multi products	15-35
F	Garment Technologist	30	Large Retailer/Mail order	Middle	Womenswear Formal and casual knitted and woven Multi products	25-45
G	Pattern Cutter/	13	Small Supplier	Value	Young women's jersey wear	15-25

	Garment Technologist					
H	Garment Technologist Product Developer	9 ½	Medium Sized Supplier Importer	Value	Menswear Casual denims Shirts and jersey wear	20-35
I	Sourcing Manager	20	Small Branded Supplier/Mail order	Middle-Higher	Men & Women's Performance & sports outerwear	30+

Table 1. Subject Profiles

The creation of a fit tool

Two garments were purposively selected by two experts in garment fit, for poor fit. The garments were purchased from a well-known High Street store and were generic, basically styled and mass-produced. They consisted of a pair of black trousers and a white short sleeved blouse. Both garments were made of a woven textile and were coded size 10.
Ill-fitting garments have been used to assess and quantify fit previously by Kohn and Ashdown (1998). As fit assessment can be subjective (Fan *et al*, 2004), the experts were then provided with a chart detailing literatures definitions of correct garment fit. From this they assessed the garment on a fit model using the Fastfit images and listed all the areas of poor fit according to the criteria from literature. This was tabulated and good fit was compared with the garments actual fit (Table 2) which was paired with Fastfit visuals of the areas of poor fit (Figure 1). The trousers had six areas of poor fit and the blouse had ten. The visuals were shown to the subjects but not the table.

Many manufacturers use the hourglass shape when defining their fit model (Connell *et al,* 2001), and most clothing patterns are designed for standard posture (Fan *et al*, 2004; Kohn & Ashdown, 1998). These two criterions determined the shape and posture of the fit model. A size 10 model was selected and filmed using Fastfit 360° (Figure 1) to enable the garments to be viewed on a personal computer (PC) at 360°. This simulated the garment fitting session.

Blouse back	
Good fit	Actual fit
The back should appear smooth and there should be no strain or bagginess at the armhole seam (Lee & Hawksley, 1984, Betzina, 2003). There should be sufficient ease to move the arms forward (Fan *et al*, 2004, Brown & Rice, 2001). The fabric should lie smoothly between the creases of the body and the arm (Liechty *et al*, 1992).	Vertical creases were observed running along the back armhole edge, and there were diagonal creases originating under the shoulder blades and running downward to the side waist point on the side seam (Figure 1). The fabric of the garment appeared buckled and collapsed from the back waist to hem (Figure 1).

Table 2. Fit Assessment Chart – Blouse Back

Figure 1 Fit Assessment Visuals – Blouse Back

Interviews

Subjects were interviewed separately and they had no prior knowledge of the questions. Subjects were asked the same set of questions on garment development, sizing, ease and the fit process. They were also asked where garments were sampled and made. Interviews consisted of a series of questions and visuals designed to gather data on the process or role structure the subject worked within. It also informed the interviewer of how the subject operated within that process and what strategies or tools they used. Open-ended questions encouraged subjects to reflect on how their knowledge was acquired generating further insight for the study. The interviews were recorded so the content could be coded and analysed for meanings.

Observation

The subjects were shown the same FastFit images on the same equipment. Images were repeatedly shown until the subject felt they had observed enough to pass comment. Magnified portions of the garments could be viewed if subjects felt details unclear. Subjects were asked for their thoughts on both garments. If poor fit was detected subjects were asked to specify location and verbalise what they thought the problem was. They were asked if they could recommend solutions, which could be applied to the pattern to eliminate the fit problem. Observation provided the study with evidence of the practitioners' knowledge regarding the assessment of fit and the provision of appropriate solutions. It also highlighted any discrepancies of knowledge or skill set between the mix of market levels or product categories. Subjects comfort levels with the data gathering process was also observed and noted. Some results were tabulated to allow for comparative analysis.

Findings and discussion

Dual roles and skills dilution

Contextual information on the subject indicated five out of eight subjects had two job titles and were required to work across two roles. Alternating roles included creating garments, amending them and checking their quality. These cross-departmental roles inevitably required a dilution of focus from any specific role. This study identified that companies may be attempting to overcome shortages by requiring employees to undertake more than one role. Furthermore, Winterton and Winterton (2002) stated that to make clothing practitioners who possess specialist skills branch out to become multi-skilled in another specialised area, as an addition to their role, resulted in a dilution of the skills deployed. It is therefore striking that this study has found that that the majority of subjects sampled are required to work in dual roles at a specialist level in the industry. It could however be argued that the possession of multiple skills in more than one department may be beneficial. Vouyouka (2007) states that clothing practitioners, especially designers would benefit from a greater understanding and knowledge of the technical as well the aesthetic aspects of the industry, as this could improve clothing fit. However, this study found subjects who were required to work within multiple roles commented that time and manpower were very limited and that more could be done to improve fit if they had more time and personnel. Subjects required to work in one role also stated tight critical path schedules dictated they approve for manufacture garments whose fit they were not 100% happy with. All subjects worked to tight deadlines as garments needed to be approved in a timely manner so offshore production was not delayed. Resourcing new suppliers for manufacture was viewed by subjects as common practice. Responses indicated this practice introduced further delays as new working relationships needed to be bedded in.

Sizing

This study wanted to ascertain the starting point for the development of a size chart and what was perceived to be the determining factor in their creation. To establish this, the study asked specific questions (Table 3). Seven subjects stated their company provides them with a garment size chart rather than a body size chart whilst one subject stated they had access to both (Table 3). This would certainly indicate that those seven companies regard garment-based size charts as more important or relevant than body size charts.

Does your company provide a body or garment size chart or both?		
Subject	Body	Garment
B		✓
C		✓
D	✓	✓
E		✓
F		✓
G		✓
H		✓

I		✓

Table 3 Does your company use a body or size chart

Subjects were then asked which they thought more important in the development of a garment. Five out of eight subjects confirmed a garment size chart as being more important than a body size chart (Table 4). All eight subjects thought that bought samples adequately provided the size information necessary to develop a garment (Table 4), although only subject D thought this would be adequate as a starting point in the garment development process. Subject F stated a body size was more important in the development of a garment but later stated they were required to work from historical size charts of garments that have sold well. Most indicated that because the garment would be fitted on a model or mannequin during the fit process that would be sufficient to amend the size chart to their target customer at that point rather than at the inception of the garment. This time saving strategy utilising the measurements of bought samples for a garment size chart seems a false economy, as the garment then has to be refitted to the target customer size. This finding indicates measuring garments for size and fit is not only a frequent occurrence but has been accepted by many practitioners as good practice. Responses such as ***'Nobody ever complained about the fit. It did seem to do the job it needed to do***' (Subject I) confirmed this, however, subject I also admitted that, '***It wasn't produced in a terribly professional manner'***.

Which size chart do you think is more important in the development of the garment?	
Subject	Responses
B	Garment – '***I think that the garment size chart during my working practice would make life easier because the fit model[s]… weight would go up and down'.***
C	Body - ***'but we have a garment size chart and it is a size chart that has developed throughout the years'***.
D	Garment - '***The size charts that we refer to are always production size charts. So they will have come from initially a proto sample provided by a supplier'***.
E	Garment - '***We basically work on fixing samples. We take measurements from samples and grade then accordingly. And we fit on the body or on the dummy***'**.**
F	Body - '***I think body***'.
G	Body - ***'but 4 weeks turnaround makes it impractical, you need basic garment size chart'***.
H	Garment - ***'we get the buying samples from where we develop; we fit it and where we develop our own spec sheets from there'***.
I	Garment - '***It wasn't produced in a terribly professional manner'***.

Table 4 which type of size chart is more important to garment development

It was established garment block/pattern dimensions were mainly created from purchased samples. Subjects' response suggests this is an acceptable practice. Simmons et al (2004) stated that regardless of who defines fit it must always begin from basic human measurements and proportions and part of the reason the clothing industry struggles with fit is because they have strayed so far away from human measurements. Connell et al (2001) stated that the loss of direct engineering knowledge to link patterns with body size and shape contributes to problems industry has with clothing fit. This study concur with Simmons et al (2004) and Connell et al (2001) in identifying the problem of fit being a conflation of a movement away from basic human measurements and the loss of direct engineering knowledge. If companies do not work with body size charts it is unlikely that they will adopt new technologies such as the 3D body scanner as these technologies provide processes and tools which are unfamiliar to industry's existing practices.

Ease

The question of ease in terms of definition and application was posed. This was to establish if subjects understood and considered the element of ease allowance within size charts and garment patterns. The findings indicated mixed response, with reference being made to the use of ease as a production term and ease as the extra measurement over the body measurement. Subjects who discussed the latter definition explained they had learned to apply ease either by rote (learned from senior colleagues) or in a heuristic manner and therefore offered no definite calculation method. Learning ease values in this manner has serious consequences for the UK clothing industry as skills are being lost due to off-shoring samples. Correct ease allowances are integral to correct fit (Brown & Rice, 2001) and if this is not clearly understood fit is compromised.

Fit meetings

The study found the garment would undergo two fit assessments in two fit meetings. This first meeting was prior to the retailers' fit meeting to check the garment measured the specifications and to reduce any worries on the part of the supplier. Given the time constraints imposed by the clothing industry to speed up clothing deliveries to the consumer, this seems an unnecessary waste of time as subjects were assessing the same garment twice. Subjects were often anxious about using new off shore manufacturers; this is because subjects stated that the factories they used could not consistently be relied upon to produce a garment to the exact specifications. The responses identify communication, subjectivity and lack of on-sight control as being issues which affect the way a garment will fit. Subjects C, D and E, who work in both the middle and value end of the market, gave anecdotal evidence of these issues and their responses indicated frustration, which was not helped by having to work within tight time constraints.

Interview results also show all subjects used one fit model to fit garments of a base size on. In all cases the model was not measured on a frequent basis. By not monitoring the model's measurements it is unclear if problems in garment fit are due to changes in the model's dimensions or general poor garment fit. Subjects did not consider this as a problem but did acknowledge that it would be preferable to fit samples on more than one person thereby checking fit on a broader range of body shapes. However, subjects stated the use of more than one fit model was a 'luxury'(Subject D) and 'the best scenario'(Subject F) and would only be possible if there were major problems with fit. Findings identified a culture of arbitrary size chart creation, a haphazard approach to block development and disagreements over fitting a garment leading to the redesigning of garments rather than fitting. Therefore, it is unsurprising that practitioners have misidentified the measuring of fit models as being of little consequence in the fit process and so further exacerbating fit problems.

Subjects thoughts on Fastfit

Subjects were interested in experiencing Fastfit as they had no access to the technology. It was suggested the technology would be useful for working with overseas factories as small problems could be observed and remedied quickly. Many thought the visual of the trousers was harder to see and subject I refused to assess the garment because of this. They all said they would not approve a final sample using this technology alone and some said it would be more informative for them if they could touch the garment.

Trousers fit assessment

Subjects did not identify every area of poor fit. Subject F who had the most experience (30 years) and subject D (20 years) located the majority of poor fit areas (three out of six) and provided very comprehensive fit amendments using verbal descriptions and illustrations. It may be significant that both subjects worked for large organisations and had only one role to perform.

Blouse fit assessment

The second garment was easier to assess, perhaps due to colour choice. All subjects assessed the garment's fit. Most but not all areas of poor fit were identified with subjects D and F locating six out of ten areas of poor fit. Amendments to remedy poor fit were varied in method and level of detail. The results again identified Subjects F and D as being the most knowledgeable. Recognition of the fit issues appeared to be directly related to the personal perceptions of the subject and their familiarity with the fit problems. Accuracy in locating fit problems may therefore be correlated with length of time in the role. This portion of the study found that there are pronounced variations in the levels of skills of practitioners and that poor fit can be undetected or misdiagnosed if the practitioner has had little training in fit or is new to the role. The findings also provided evidence that industry is employing practitioners who are not equipped with the necessary level of skill needed to consistently assess, amend and approve garments that are of a good fit. This finding concurs with Winterton and Winterton's (2002) research which stated practitioners who are at a specialised level in the clothing industry dilute their skills if they are required to take on multi-skilled roles.

Limitations and Summary

As this paper has focused on the UK industry, it should be admitted that this may limit the findings in terms of the global industry; however it is likely there are similarities in practice with workers throughout the global supply chain. The relatively small number of participants may limit the scope of this work, although they are representative of workers within the UK High Street with varied experience. Future research may seek to include a greater number of participants with a more focussed selection to ensure a more targeted insight.

It was determined that regardless of market position or size, the fragmentation of the product development process has contributed negatively to fit in a number of ways. As the different roles are split across sites, many of which are in other parts of the world, practitioners are being distanced from the pattern development process. This de-coupling of designer and pattern cutter, sample machinist and garment technologist, production manager and quality controller, and so on, has resulted in a loss of cohesion throughout the product development process with practitioners being both anxious and resigned to losses in quality and fit. This loss of cohesion is further exacerbated through the industry practice of sourcing and re-sourcing factories for manufacturing in pursuit of cheaper production costs. All of these pressures combine to limit the amount of time available to practitioners to perfect fit and indeed a number have stated that fit is often sacrificed to commercial decisions so the product is produced on time.

The key finding identified by this study has been the overwhelming evidence of the fact that industry appears to show disregard for the use of body size charts in the generation of garments. Added to this ease is either misunderstood or added in an arbitrary fashion. This is especially interesting, as current academic research has been approaching the problem of fit from the belief that industry is using out-of-date body size charts and has been attempting to provide solutions for industry based upon this incorrect assumption. Furthermore, the latest advances in technology that aim to supply solutions to the problems of fit, technologies such as the 3D body scanner, are also approaching the problem from the perspective of the body whereas this research shows that practitioners rarely approach the generation of garments from this perspective. Whilst accepting that the current industry practices are no doubt short-sighted, particularly in the way these practices impact upon the skill sets of those involved and compound the problems of fit, it must be accepted that the success of Fast Fashion and similar sectors of the industry have created a culture that is ingrained and entrenched. It will not be easy to convince the industry to change its thinking when its current model appears so profitable.

In conclusion, academia appears to be confronted with two ways to approach this problem. In the short term, it may be necessary to refocus and attempt to provide solutions to the problem of fit that are tailored to current practices rather that providing solutions tailored to the practices academia believes industry has. This refocusing could provide solutions that could be implemented now, with the current skill sets available and within the current model. In the longer term, it must be considered that academia needs to lead industry towards a new model, based on the body rather than the garment, implemented through the application of new technologies and new practices. This will be the more difficult remedy to the problem of fit as it will require a paradigm shift in both mind-set and culture because it will involve new methods of garment generation to be taught at the training stage and extrinsic methods to be adopted by those already practising in industry.

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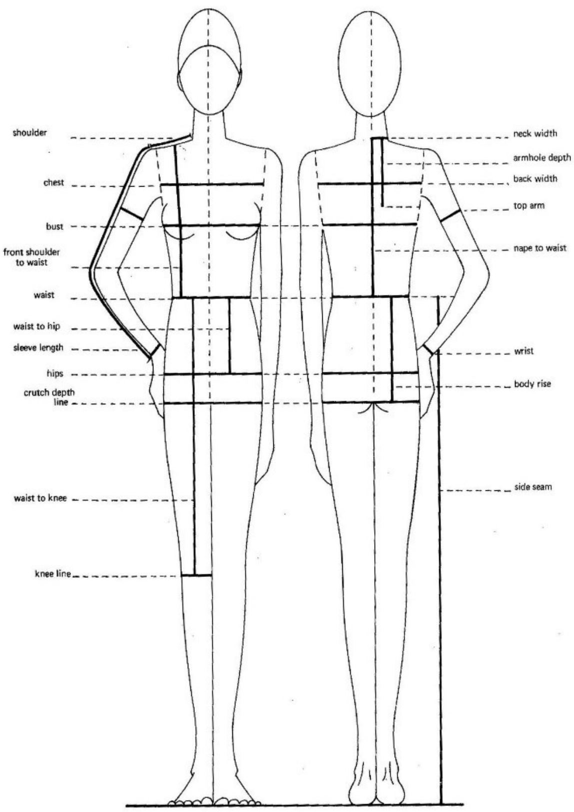
11 Appendix C

11.1 Examples of pattern literature measurement guidance

11.1.1 Aldrich, (2008)

Standard body measurements



Standard Body Measurements

SPECIAL NOTE

Some manufacturers may wish to follow the Continental system of size coding – 4cm between sizes up to size 20.

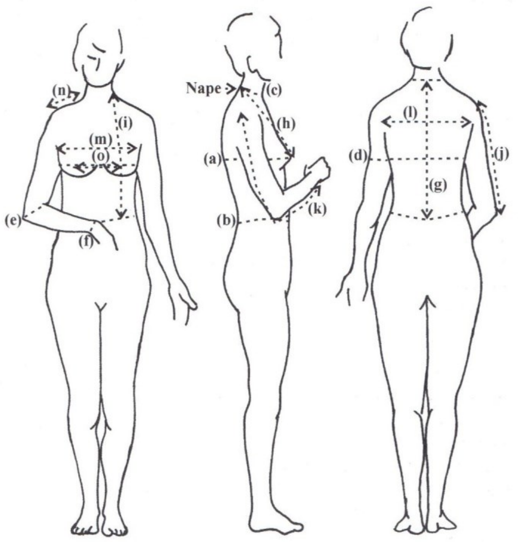
6cm between sizes above size 20. A size chart conforming to this system is on page 143
The section on grading covers grading for British Standard size coding and for Continental sizing.

SIZE SYMBOL	8	10	12	14	16	18	20	22	24	26	28	30
HORIZONTAL MEASUREMENTS												
BUST	80	84	88	92	97	102	107	112	117	122	127	132
WAIST	58	62	66	70	75	80	85	90	95	100	105	110
HIPS	85	89,	93	97	102	107	112	117	122	127	132	137
BACK WIDTH	32.4	33.4	34.4	35.4	36.6	37.8	39	40.2	41.4	42.6	43.8	45
CHEST	29.8	31.2	32.6	34	35.8	37.6	39.4	41.2	43	44.8	46.6	48.4
SHOULDER	11.75	12	12.25	12.5	12.8	13.1	13.4	13.7	14	14.3	14.6	14.9
NECK WIDTH	6.75	7	7.25	7.5	7.8	8.1	8.4	8.7	9	9.3	9.6	9.9
DART	5.8	6.4	7	7.6	8.2	8.8	9.4	10	10.6	11.2	11.8	12.4
ARMHOLE	37.5	39	40.5	42	43.5	45	46.5	48	49.5	51	52.5	54
VERTICAL MEASUREMENTS												
NAPE TO WAIST	38.5	39	39.5	40	40.5	41	41.5	42	42.5	43.	43.5	44
SHOULDER TO WAIST	38.1	38.8	39.5	40.2	40.9	41.6	42.3	43	43.7	44.4	45.1	45.8
ARMHOLE DEPTH	20	20.5	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5
WAIST TO KNEE	56	57	58	59	59.5	60	60.5	61	61.5	62	62.5	63
WAIST TO HIP	21	21.25	21.5	21.75	22	22.25	22.5	22.75	23	23.25	23.5	23.75
SLEEVE MEASUREMENT												
LENGTH TO WRIST	55.75	56.5	57.25	58	58.5	59	59.5	60	60.5	61	61.5	62
TOP ARM	24.8	26.2	27.6	29	30.5	32	33.5	35	36.5	38	39.5	41
WRIST	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20	20.5
MEASUREMENTS FOR PANTS												
BODY RISE	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32
SIDE SEAM	101	102	103	104	104.5	105	105.5	106	106.5	107	107.5	108
FINAL KNEE WIDTH	25.8	26.4	27	27.6	28.4	29.2	30	30.8	31.6	32.4	33.2	34
FINAL HEM WIDTH	25.8	26.4	27	27.6	28.4	29.2	30	30.8	31.6	32.4	33.2	34

11.1.2 Beazley and Bond (2003)

MEASURING POSITIONS FOR BODICE AND SLEEVE

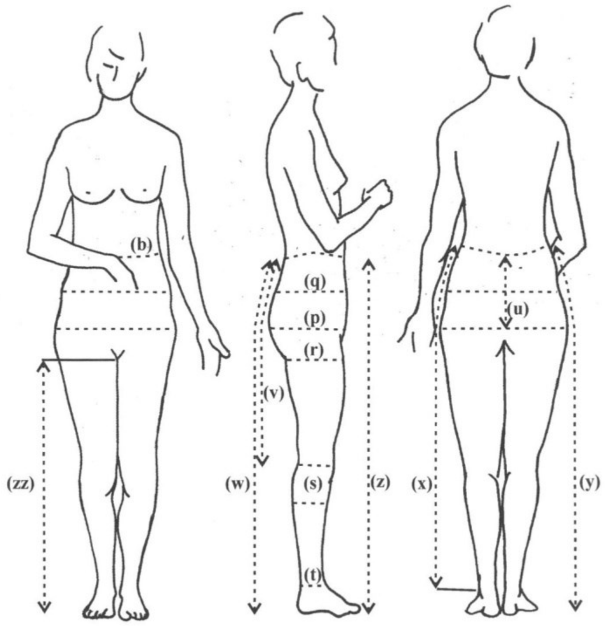
(a) Bust girth
(b) Waist girth
(c) Neck girth
(d) Upper arm girth
(e) Elbow girth
(f) Wrist girth
(g) Nape to waist
(h) Front length to bust
(i) Front waist level
(j) Elbow level
(k) Sleeve length
(l) Across back
(m) Across front
(n) Shoulder length
(o) Bust prominence width



(k) Sleeve length: Measure as 'j' and continue the tape measure to the end of the wrist bone at the 'little finger' side of the hand. (The garment centre back neck to end of shoulder measurement is subtracted to give the final sleeve length.)
(l) Across back: This width measurement is taken horizontally and gauged just above the skin folds where the arms connect to the torso.
(m) Across front: This width measurement is taken horizontally between the centre front neck and bust level. The width is gauged at the skin folds where the arms connect to the torso.
(n) Shoulder length: The highest part of the shoulder is located and measured from the base of the neck to the bone at the end of the shoulder.
(o) Bust prominence width: Measurement horizontally between the most prominent part of the left and right breasts.

MEASURING POSITIONS FOR SKIRTS AND TROUSERS

(b) Waist girth
(p) Hip girth
(q) Upper hip girth
(r) Thigh girth
(s) Knee or calf girth
(t) Ankle girth
(u) Hip level
(v) Knee length
(w) Back length
(x) Ankle length
(y) Outside leg length
(z) Front length
(zz) Inside leg length



MEASURING METHOD FOR SKIRT AND TROUSERS

(b) Waist girth: See measuring method for bodice and sleeve.

(p) Hip girth: The tape measure is positioned horizontally around the fullest part of hips and buttocks and parallel to the ground (optionally an elastic tape can be positioned and levelled by using a metre rule). A note can be made of the measurement between the centre back waist and hip level (see (u)).

(q) Upper hip girth: Measurement midway between the waist and hip levels and parallel to the ground. The correct position can be checked in the mirror.

(r) Thigh girth: The person being measured stands with her legs slightly apart. The measurement is taken horizontally around the thickest part of the right upper thigh just below the crutch level.

(s) Knee or calf girth: Measurement horizontally around the thickest part of the right knee or calf, whichever is the largest.

(t) Ankle girth: Measurement around the thickest part of the right ankle.

(u) Hip level: Measure vertically from the centre back waist and the hip level.

(v) Knee length: Measure as (u) and continue down vertically to the crease at the back of the knee. (This measurement can be used as a guide for skirt lengths.)

(w) Back length: Measure as (u) and continue vertically down the back to the ground.

(x) Ankle length: Measure vertically from the side waist, over the side hipbone down to the lower edge of the anklebone.

(y) Outside leg length: Measure as (x) and continue the tape measure vertically down to the ground.

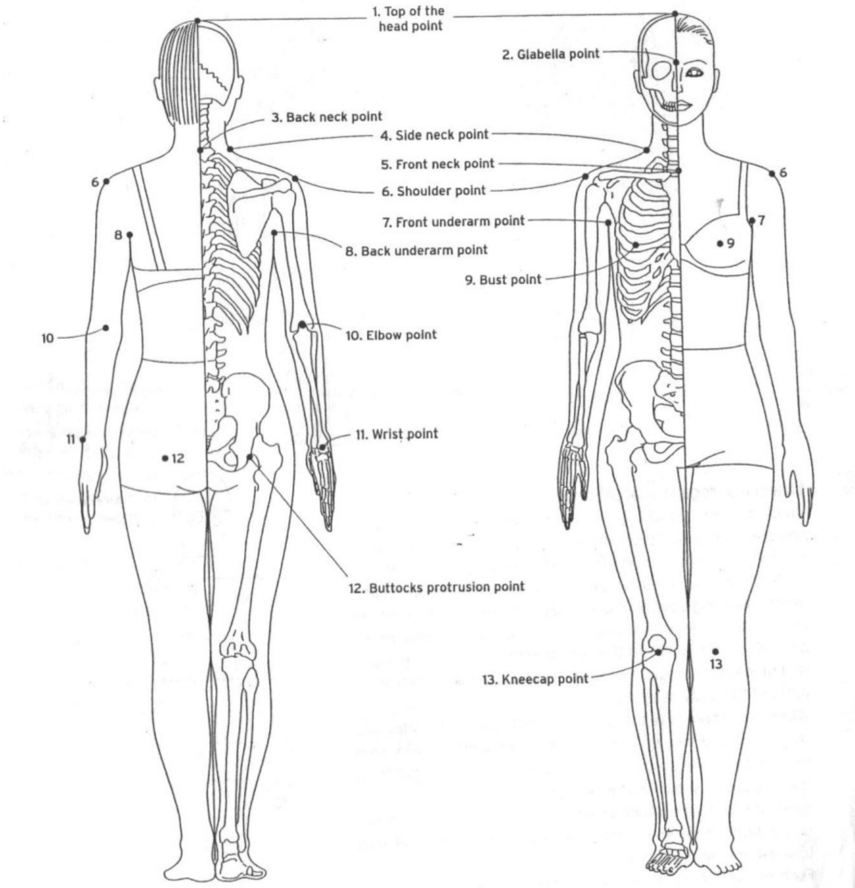
(z) Front length: Measure vertically from the centre front waist down to the ground.

(zz) Inside leg length: The person being measured can position the end of the tape measure between the legs at the crutch level. The measurer then places the tape down the inside of the leg to the ground.

Computerised body measuring systems

Various computerised body measuring systems have been developed since the early 1980s. These automatic systems operate by using scanning or photographic equipment linked to a computer. Developments since the early 2000s have realised great improvements and there are several systems now in commercial use. These systems record the body shape and posture two or three dimensionally, then calculate the body measurements. These systems can also be linked to a computer pattern alteration system or made-to-measure system (see Part 4). This enables the computer to find the nearest size pattern to the individual and alter the pattern according to

11.1.3 <u>Bunka (2008)</u>



Definitions of measurement points

	Measurement point	Definition
1	Top of the head point	Highest point at the centre of the head with the eyes kept horizontal
2	Glabella point	Point between the left and right eyebrows that protrudes outwards
3	Back neck point (BNP)	Point of protrusion of the seventh vertebra
4	Side neck point (SNP)	Intersection between the front edge of the trapezius muscle on the back and the ridge line of the shoulder
5	Front neck point (FNP)	Intersection between the line that connects the upper edge of the left and right collar bone and the anterior median line
6	Shoulder point (SP)	Intersection between the baseline of the base of the arm and the ridge line of the shoulder, positioned almost at the centre of the upper arm when viewed from the side
7	Front underarm point	Point at upper edge of the fold where the arm joins the rest of the body at the front of the area around the base of the arm
8	Back underarm point	Point at upper edge of the fold where the arm joins the rest of the body at the back of the area around the base of the arm
9	Bust point (BP)	Point at which the breasts protrude the most when the subject is wearing a bra
10	Elbow point	Point where the elbow protrudes the most
11	Wrist point	Point where the wrist protrudes
12	Buttocks protrusion point	Point at which the buttocks protrude the most
13	Kneecap point	Point on the lower edge of the kneecap

Measurement Items and Position on the Body

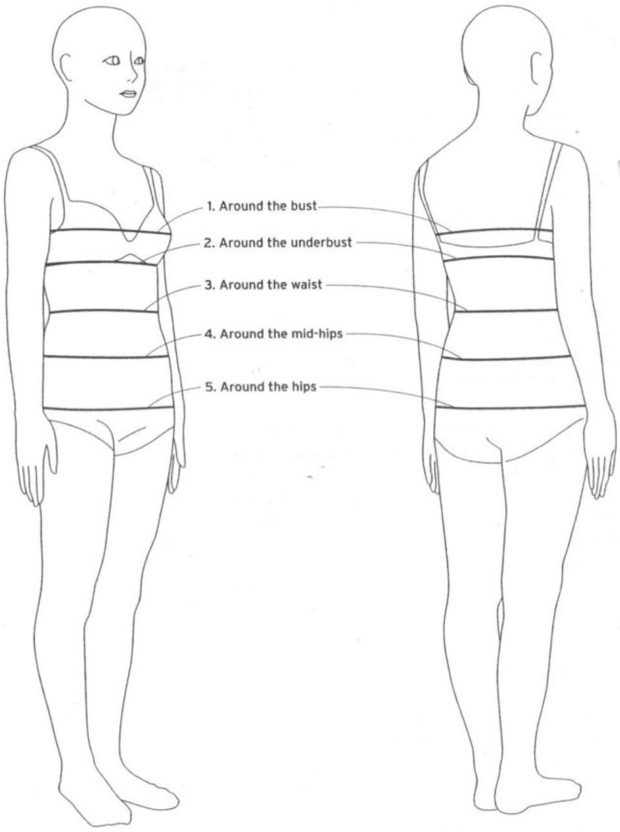
	No.	Measurement items	Position
Diametrical measurements	1	Around the bust	Horizontal diameter across the bust point
	2	Around the underbust	Horizontal diameter across the under bust (lower edge of the breasts)
	3	Around the waist	At a detailed position on the torso, horizontal diameter where a waist belt sits comfortably
	4	Around the mid-hips	Horizontal diameter of the central position of waist and hips
	5	Around the hips	Horizontal diameter across the position where the buttocks most protrude, with a celluloid plate applied to the abdomen
	6	Around the base of the arm	Diameter of the base of the arm across the front underarm point, the shoulder point and back underarm point
	7	Around the upper arm	Diameter of the position where the upper arm is widest
	8	Around the elbow	Diameter of the position where the elbow is widest across the elbow point
	9	Around the wrist	Diameter of the position where the wrist is widest across the wrist point
	10	Around the palm of the hand	Diameter of the position where the base of the fingers is widest with the thumb resting lightly in the palm of the hand
	11	Around the head	Diameter of the position where the back of the head most protrudes across the glabella point
	12	Around the base of the neck	Diameter across the back neck point, the side neck point and the front neck point
	13	Around the thigh	Diameter of the position where the thigh is widest, under the groove between the buttocks and the thigh
	14	Around the lower leg	Diameter of the position where the calf is widest
Width measurements	15	Back and shoulders width	Length of the body surface from the left shoulder point to the right shoulder point across the back neck point
	16	Back width	Length of the body surface between the left back underarm point and the right back underarm point
	17	Chest width	Length of the body surface between the left front underarm point and the right front underarm point
	18	Space between bust points	Distance between left and right bust points
Height measurements	19	Height	Distance from the top of the head point to the floor
	20	Total length	Distance from the back neck point to the floor
	21	Centre back length	At the centre back, distance from the back neck point to the waist
	22	Back length	Distance from the side neck point to the waist through the point of protrusion of the scapula
	23	Side neck point to bust point	Distance from the side neck to the bust point
	24	Front length	Distance from the side neck point to the waist through the bust point
	25	Sleeve length	Distance from the shoulder point to the wrist point
	26	Waist height	Distance from the waist to the floor
	27	Hip height	Distance from the buttocks protrusion point to the floor
	28	Hip depth	Distance where hip height is subtracted from waist height
	29	Crotch length	Distance where inseam length is subtracted from waist height
	30	Inseam length	Distance from the crotch to the floor
	31	Knee length	Turned towards the front, distance from the waist to the lower edge of the kneecap
Other	32	Front and back crotch length	Distance from the front waist under the crotch to the back waist
	33	Weight	Physical weight in special underwear designed for taking physical measurements

❷ Measurements and methods of measurement

Following is an explanation of the various body measurements required for garment production that include the diameter, the width and length of the body, and methods for taking those measurements.
Note: The numbering of the measurement items is in accordance with the table on page 58.

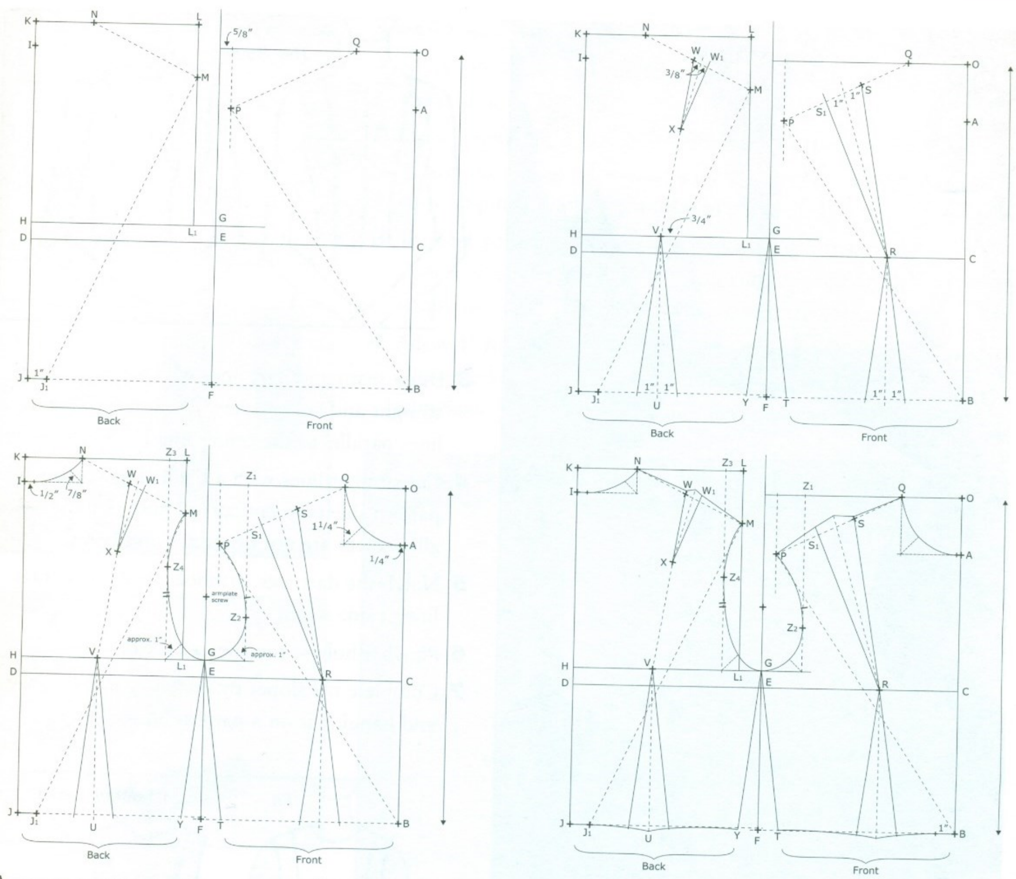
1. Around the bust
2. Around the underbust
3. Around the waist
4. Around the mid-hips
5. Around the hips

Take measurements by running the tape measure around each measurement point, keeping it horizontal.



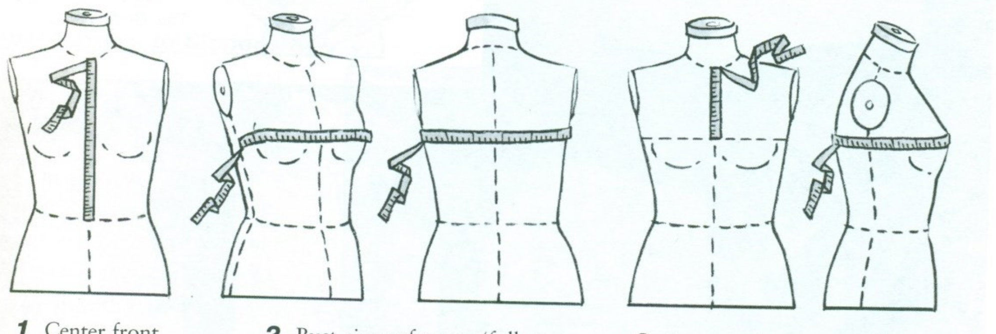
11.1.4 Abling and Maggio, (2009)

Drafting the Bodice from Measurements



Accurate measurements are required to draft a bodice sloper. Carefully measure the dress form or human figure and record these illustrated measurements. The following pages provide step-by-step drafting instructions.

Measuring the Dress Form

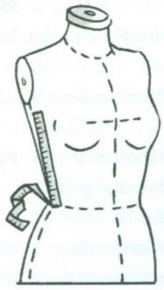


1 Center front length (base of neck to waist)

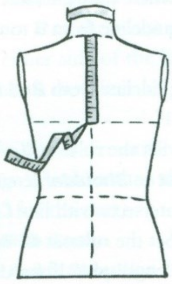
2 Bust circumference (fullest part at bust level). Pin tape parallel to the floor

3 Front neck to bust level

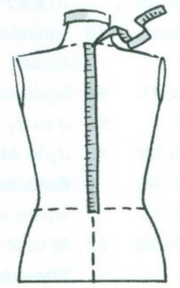
4 ½ bust circumference CF to CB



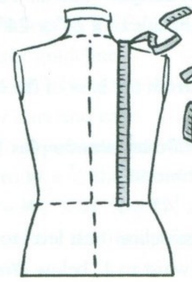
5 Side seam (waist to 1″ below arm plate)



6 Back neck to bust level

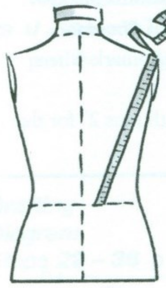


7 Center back length (base of neck to waist)

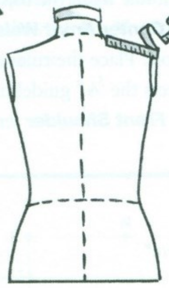


8 Back shoulder, neck to waist

9 Across back shoulder (armhole to armhole)

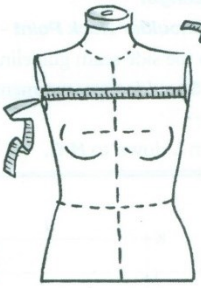


10 Back waist to shoulder (1″ from CB waist to end of shoulder)

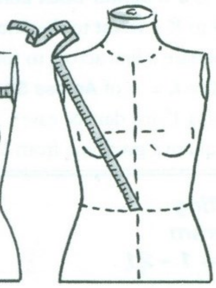


11 Back shoulder (base of neck to end of shoulder)

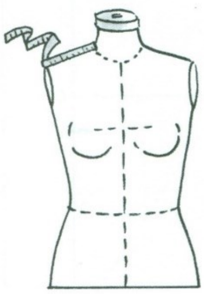
12 Front shoulder neck to waist



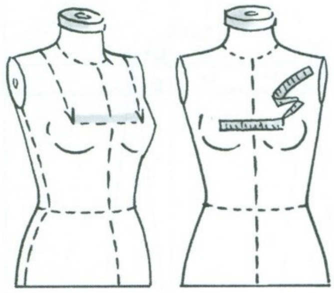
13 Across front chest



14 Front waist to shoulder

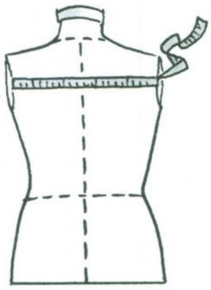


15 Front shoulder length



16 Bust point to bust point

17 Waist circumference



18 Across back

11.1.5 Bray, (1986)

HOW TO TAKE MEASUREMENTS

BODICE MEASUREMENTS

1. **Bust**—round the fullest part of the bust in the front, *raising the tape slightly* to a level just below the shoulder blades in the back. Measuring quite close to the figure, *almost tightly in small sizes* (less so in large sizes).
2. **Hips**—round the fullest part of the hips, average 22 cm below the waist (20–25 cm). Measuring very close to the figure, even tightly in smaller sizes.
3. **Waist**—round the natural waist, measuring only as tightly as a skirt band should fit (small waists can easily be pulled in too much).
4. **Back width**—across the back, approximately 10–12 cm below the nape of the neck. This should be a generous measurement, allowing for any natural stoop, and the person measured should not stand more erect than usual.
5. **Chest width**—across the chest, fairly low, approximately 12–13 cm down from the base of the neck, with shoulders thrown well back. (In Trade Charts this measurement is often taken 2–4 cm higher and therefore registers 1–2·5 cm less.)
6. **Shoulder**—down the middle of the shoulder, from neck (NP) to point of shoulder (SP) where the sleeve begins. This measurement tends to be *influenced by fashion.*
7. **Back Length to waist**—down the CB from nape to natural waist. This measurement tends to be influenced by both personal taste and fashion.
8. **Front Length to waist**—is taken down the front from Neck Point (NP), i.e. the highest point of the shoulder (which is easy to establish), over the fullest part of the bust to the waist. (In Trade Charts this measurement is often required to be taken from the *middle of the shoulder.*) This is an optional measurement which, though useful, particularly for checking *shape* of figure, must be used with great care and not exaggerated. It is unnecessary for a draft made to *average* measurements.

SLEEVE MEASUREMENTS

1. **Top Arm measurement**—round the fullest part of the arm, passing the tape high under the arm and joining it on the top 10–12 cm below the point of the shoulder. The measurement, which tends to be influenced by fashion, is an easy one at present.
2. **Length of Arm**—from top of arm, i.e. Shoulder Point (SP), passing over the elbow point down to the *back of* the wrist, above the little finger. The arm should be bent at the elbow. The length is influenced by personal taste, less by fashion.
3. **Length to Elbow**—from the same point as above, down to the elbow point (not too long).
4. **Elbow width**—round the elbow, passing exactly over the elbow point, with the arm well bent. Nothing is added to it in tight sleeves, so it must be big enough to allow for comfortable bending of the elbow.
5. **Wrist**—round the wrist, a close measurement, but not too tight.

SKIRT MEASUREMENTS

(in addition to Hips and Waist given above)

Skirt Length—down the CF, from the waist, as long as required. This measurement varies, of course, for different types of skirt, so the Skirt block is made to the most usual length worn, and this length is the one noted in the list of measurements. This measurement is also influenced considerably by personal taste and particularly by fashion, changing more frequently than any other.

The Length to the ground can be taken at the same time, and the difference between the two noted.

AVERAGE SIZES

In considering the question of 'Sizes', it is important to differentiate between those based on body measurements and those based on the final size of the garment. The two are frequently confused, creating difficulties both in the production and in the sale of ready-to-wear clothing. The measurements given in the **Table of Average Measurements and Proportions** are all body measurements, i.e. **nett measurements to which nothing has been added for fit.** Throughout this system these nett measurements are the basis of '*Size*', which always applies to *the figure to be fitted* and not to the garment that fits it. It is the cutter's responsibility to know how to produce a garment to fit each 'Size' in keeping with style and current fashion.

A different approach to this question exists in the wholesale trade, where 'Size' is often the size of *the actual garment for which a figure must be found* and many wholesale Size Charts consist of *theoretical sizes.* The problem is further complicated by the variety of ways used to describe the 'Sizes', such as 'English size 40', or 'American size 16', or 'French size 42', or in some English firms the 'W' size, etc.

The modern trend, however, is for the 'Size' to be more directly related to a body measurement (e.g. the Bust, Hips, Waist or Height), responsibility for the actual size or *fit* of the garment being left to the skill and judgement of the cutter.

All the 'Sizes' referred to throughout this book are based either on the Bust measurement (for blouses, dresses, coats) or on the Hip measurement (for skirts) and are graded every 4 cm, as shown in the table on p. 16.

may break down completely in practice, either because the cutter has not mastered it sufficiently, or the figure does not conform to theory in some important respect, or for some other personal or technical reason, such as a customer's preference, a difficult fabric and so on. There is nothing more discouraging than producing an ill-fitting garment, or even one which simply does not please the customer, after one has spent time and effort on a complicated system of taking measurements. It is far better to rely on a few simple measurements, applied with skill and understanding, and to leave a reasonable margin for possible adjustments at the fitting.

There are **Basic Measurements**, which are essential for the construction of every pattern, and **Supplementary Measurements**, which may be useful when working on a particular design or for a particular figure. The choice and number of the latter depend on various circumstances and are influenced not only by style and fashion but also by the ideas, experience and working methods of the cutter. Some cutters use no such extra measurements, either for ensuring better fit or for style planning, for they prefer to make all the necessary adjustments at a fitting. Others, on the contrary, like to do more planning ahead and to provide for the difficulties of fit and style at the pattern-making stage, considering a fitting as a mere checking of results. Many of the more experienced cutter-fitters belong to this group and, while measuring a person, they take their own additional measurements and notes on the shape of the figure, for which no general instructions can be given.

BASIC MEASUREMENTS

BODICE

1. Bust
2. Hips
3. Waist
4. Back width
5. Chest width
6. Shoulder
7. CB Length to Waist

Front Length to Waist is an optional measurement

SLEEVE

1. Top Arm measurement
2. Length of Arm
3. Length to Elbow
4. Elbow width
5. Wrist

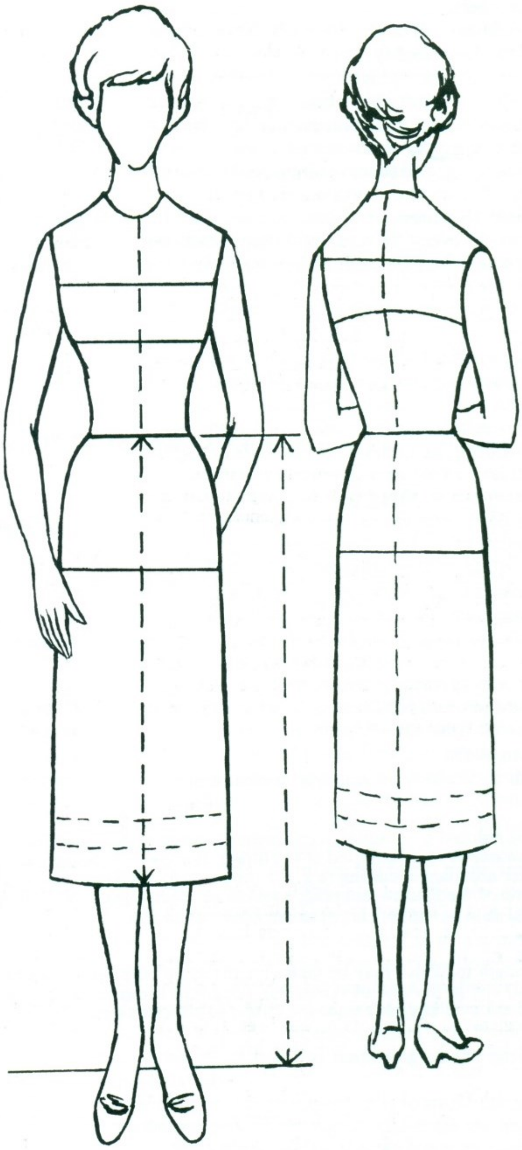
SKIRT

1. Hips } as for bodice
2. Waist } as for bodice
3. Length

Length to the ground is optional

This list could be reduced by omitting measurements 5 and 6 for the bodice, and 3, 4 and even 5 for the sleeve, replacing them by *average measurements* to be adjusted at the fitting. It is convenient, however, to have these individual measurements, not only because of greater accuracy in cutting (e.g. for the pattern of a Tight sleeve) but also because they are a useful indicator of the *shape* and *posture* of the figure—stooping, average or erect, square or sloping shouldered. All these measurements provide a cutter with useful data to support his personal observation.

The 'Front Length to Waist' may be taken for the same purpose, i.e. to confirm observation of the shape of the figure (prominent high bust) and in the case of skirts, the 'Length to the ground' can be useful to record the height of the figure and possibly to emphasize a person's preference for longer or shorter skirts.



MEASUREMENTS

BUST
HIPS
WAIST
CB LENGTH TO WAIST
BACK WIDTH
CHEST WIDTH
SHOULDER
TOP ARM
LENGTH OF ARM
LENGTH TO ELBOW
ELBOW WIDTH
WRIST
SKIRT LENGTH

11.1.6 Chunman-Lo, (2013)

KEY MEASUREMENTS

Nape to waist	16in (41cm)	Actual nape to waist measurement
Bust	37¾in (96cm)	35½in (90cm) + 2¼in (6cm) ease
Waist	27½in (70cm)	26in (66.5cm) + *1½in (3.5cm) ease
Front cross shoulder	14½in (37cm)	This is exact
Back cross shoulder	15in (38cm)	This is exact
Shoulder length	5in (11.5cm)	From high point shoulder, exact length
Cross front (armhole)	13¼in (33.5cm)	13in (33cm) + ¼in (0.5cm) ease
Cross back (armhole)	15 in (38cm)	14⅝in (37cm) + ⅜in (1cm) ease
Front body length	17¼in (44cm)	This is exact
Back body length	17in (43cm)	This is exact
Neck circumference	15in (38cm)	This is exact (and minimum)
Armhole circumference	16½in (42cm)	15in (38.5cm) + 1½in (3.5cm) ease
Armhole depth	6⅞in (17.5cm)	6½in (16.5cm) + ⅜in (1cm) ease

*it is recommended to include sufficient bust ease at the beginning: 2¼in (6cm) is a starting point

Nape to waist 16in (41cm)
Pattern makers do sometimes draft the bodice block ⅜in (1cm) shorter than the actual nape to waist measurement. A shorter top bodice looks more pleasing because the wearer will look taller, while a longer top bodice may create excess fabric at the waistline, making the garment look ill-fitting (see page 79).

Bust 35½ + 2¼in ease (90 + 6cm) 37¾in (96cm)
Ease is added to the bust to allow for easy movement. If the garment proves too big, then it is easier to take in the excess on both side seams or across the center front and back and side seams together.

Waist 26 + 1½in ease (66.5 + 3.5cm) 27½in (70cm)
Ease is also added to this measurement to allow for easy movement. Excess fabric can be removed in the same way as for the bust.

Front cross shoulder 14½in (37cm)
Using this measurement ensures that the shoulder of the garment sits in the right place by helping to locate the width between both shoulder points, and also to locate the shoulder slants (see Step 5, page 48). There is not, however, an exact place to take the measurement. Fashion trends and designs also influence the position at which this measurement is taken, which will vary according to the desired fit of the bodice.

Back cross shoulder 15in (38cm)
This is measured in the same way as the front cross shoulder. The two do not have to be exactly the same; a wider back cross shoulder indicates that the person has a curved back, while a narrow back cross shoulder indicates that the person stands with an arched back.

Shoulder length 5in (12.5cm)
Each company specifies its own shoulder length measurement as the "silhouette" or "signature" of a garment begins with the width of the shoulder. The average measurement for the Western market is 4½in (11.5cm), while 4 to 4¼in (10–11cm) is the average for an Eastern market.

Cross front (armhole) 13 +¼in ease (33 + 0.5cm) 13¼in (33.5cm)
This is measured 5in (13cm) down from the high point shoulder (HPS), horizontally across the body between the two front armholes. This measurement assists easy drafting of the mid-curve front armhole.

Cross back (armhole) 14⅝ + ⅜in ease (37 + 1cm) 15in (38cm)
Like the cross front, this is measured 5 in (13cm) from the high point shoulder, horizontally across the body between the two back armholes. Genuine allowance must be added to this measurement to allow adequate material to enable the arms to move forward.

Front body length 17¼in (44cm)
This is measured from the HPS to the bust point and then to waist level. This must be taken into account, especially if the bust size is larger, because the front bodice will then need to be longer than the back bodice to avoid the garment lifting up at the front (see page 55).

Back body length 17in (43cm)
This is measured from the HPS to the shoulder blade and then down to waist level. Again, this measurement should be taken into account, especially if the back is rounded when the measurement might be longer.

Neck circumference 15in (38cm)
A measurement of 15in (38cm) is the minimum that should be allowed. A neckline cannot be too tight. After drafting both the front and back necklines it is important to measure the neck circumference on the pattern to double-check if it is comfortable.

Armhole circ. 15½ + 1½in ease (38.5 + 3.5cm) 17in (42cm)
This measurement is crucial as armholes that are too small are very uncomfortable and the garment will be impossible to wear.

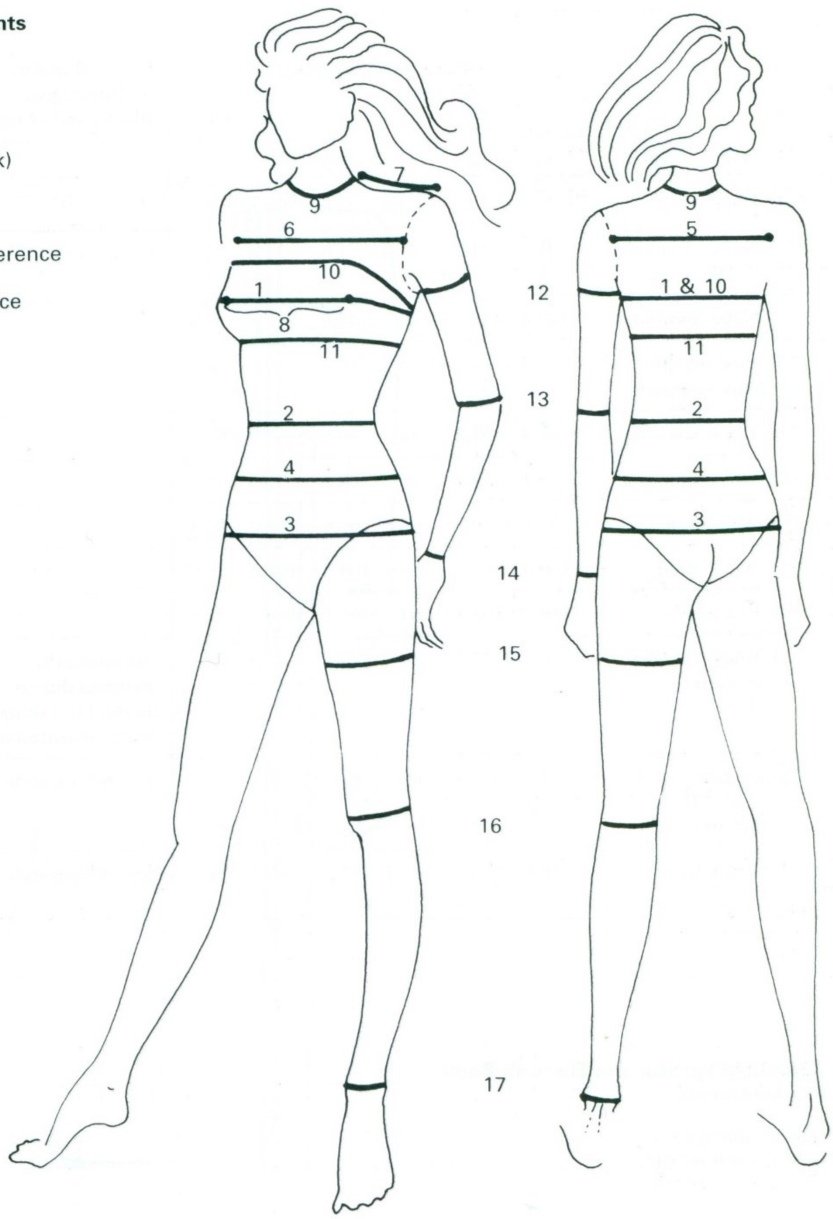
Armhole depth 6½ + ⅜in ease (16.5 + 1cm) 6⅞in (17.5cm)
An average armhole depth is 6¼in (16cm) and should not be equated to the plastic plate on a form.

11.1.7 Haggar, (2004)

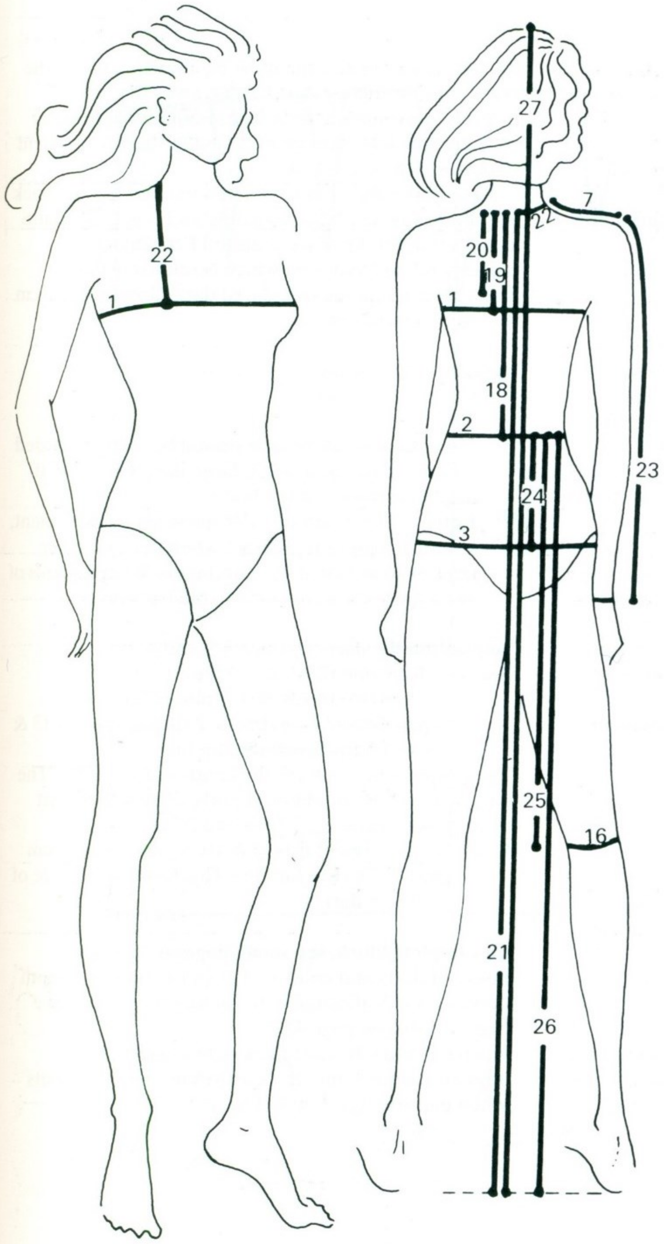
Women's Standard Size Chart

Horizontal Measurements

(1) Bust
(2) Waist
(3) Hips
(4) Top hips
(5) Back width (X back)
(6) Chest width
(7) Shoulder
(8) Bust separation
(9) Neckbase circumference
(10) Rib cage
(11) Chest circumference
(12) Top arm
(13) Elbow
(14) Wrist
(15) Thigh
(16) Knee
(17) Ankle



Women's Standard Size Chart



Vertical Measurements

(18) Nape–waist
(19) Nape–bust
(20) Nape–armhole depth
(21) Nape–ground
(22) Bust height, from nape–nipple
(23) Top sleeve length
(24) Waist–hip
(25) Waist–knee
(26) Waist–floor
(27) Full height

11.1.8 Knowles, (2005)

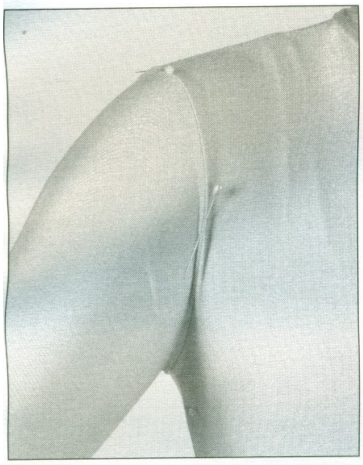


Figure 2.6

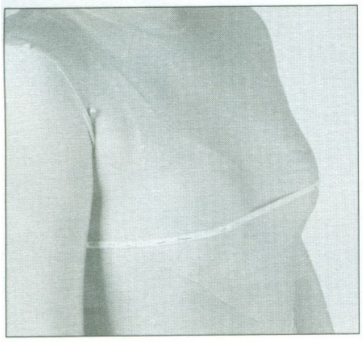


Figure 2.7


Figure 2.8

Figure 2.6

4. Have the model raise her arm about 45 degrees from the floor and swing it slightly toward the center front until a crease forms, which marks where the front mid-armhole will be. Mark this point with a pin, chalk, or a tailor tack.

Figure 2.7

5. Establish the bust level. The apex or bust point position is at the nipple. The apex marks the fullest portion of the bust mound. Mark the apexes with chalk, tailor tacks, or pins. The apexes should be the same height from the floor. Pin a length of narrow elastic from apex to apex without slack. Continue pinning the elastic around the model, keeping an equal distance from the floor, to establish the bust level. Sew the elastic onto the model's bodysuit so this position does not change for future fittings. Elastic stretches as your model removes the bodysuit.

Figure 2.8

6. Establish the waistline. Have your model bend to the side at the waist. A crease will form at the natural waistline. Check that her underwear is not creating a false waist position. Mark the waistline first with a pin or chalk, then pin narrow elastic around the model's body. The waistline may dip down in the back, which is normal for women. Sew the elastic onto the bodysuit for future fittings.

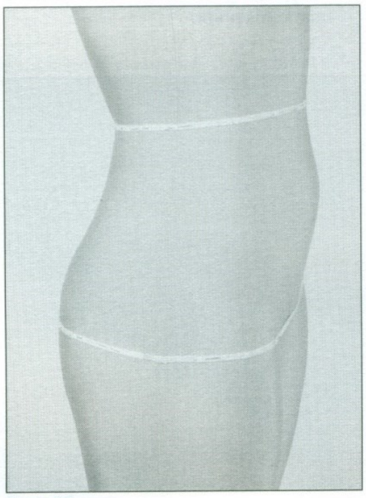


Figure 2.9

Figure 2.9

7. Establish the hip level. Find the largest circumference of the hips and buttocks by measuring at several levels on the body. Once you've found the level of the largest circumference, mark it with elastic parallel to the floor to establish the hip level. Sew the elastic onto the model's bodysuit for future fittings.

Figure 2.10

8. Establish the center back neck position. This is found by pressing with your thumb or a finger in this area to find a dip between two prominent bones, which are vertebrae. Mark with chalk, a tailor tack or a pin.

Figure 2.11

9. To mark the crease in the back mid-armhole, leave your model's arm hanging down. First, establish the **shoulder blade level** on the model. Measure the center back from the neckline down to the waist = ________________, then divide this measurement by 4: ________________ ÷ 4 = ________________.
Using this final measurement, measure from the neckline down along the center back and place a pin or tailor tack at this point. A line going through this point parallel to the floor is called the shoulder blade level. The back armhole seam runs along the crease formed between your model's body and arm with

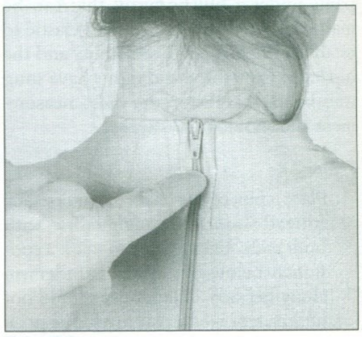


Figure 2.10

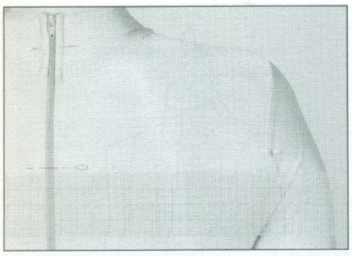


Figure 2.11

the arm hanging down. The intersection of the shoulder blade level and the armhole is called the back mid-armhole.

Figure 2.12

10. Establish the shoulder/neckline intersection. Visualize where the curve of the neckline seam would be if your model were wearing a collar that hugged the neck. (The collar in this photo is set too far from the natural neckline seam; thus, the pin mark is on the collar itself.) This position should also intersect at the top of the shoulder curve.

Figure 2.13

11. Establish the underarm/side seam intersection. The side seam of your model's body suit may not be in the correct position, so you will need to mark this intersection with a pin, tailor tack, or chalk. This point should line up in the center of the underarm on the model's upper rib cage and should intersect with the pin that is placed 1 inch below the underarm.

Figure 2.14

12. Establish the side seam/waist intersection. Again, keep in mind that the side seam of your model's body suit may not be in the correct position. Visualize a straight line (or use a long ruler) going halfway between the front and back of the model's leg and continuing straight up to the waist, and mark this point.

Upper Torso Measurements

Avoid pulling the tape measure tightly over the body as this will distort the measurements. Be gentle. Do not let a live model hold in her stomach or stand in an unnatural position. The following steps are shown on a body form, but the same measurements are needed if using a live model.

#1 (Figure 2.15)
Total shoulder girth level = _____________.

Measure all the way around the upper arms and body with tape measure parallel to the floor. If your body form does not

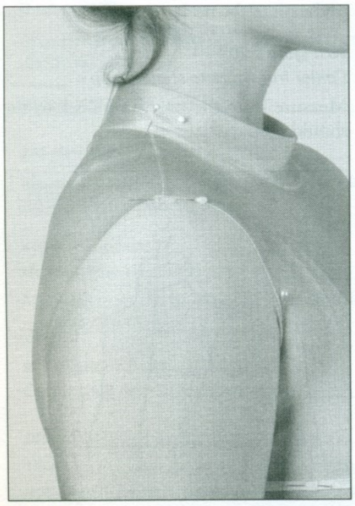


Figure 2.12

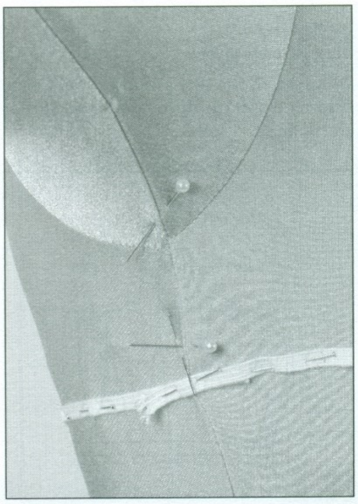


Figure 2.13

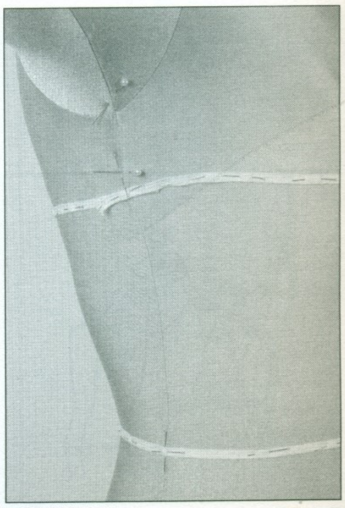


Figure 2.14

11.1.9 Shoban and Ward, (2011)

10 cm below the waist. This is a critical measurement for tight skirts.

4 Hip girth
Place the tape around the fullest part of the hip. Use the hip bone (trochanter) as a guide. This measurement should be taken firmly.

5 Half across back
Approximately 10.5 cm down from nape. Use the armhole seams as a guide. Measure generously.

6 Armhole girth
This measurement must be taken loosely from the front shoulder point down to the armhole line, and up again to the back shoulder point. You are advised to use the size chart for this measurement.

7 Neck base girth
Measure around the base of neck, and apply the tape measure fairly loosely. (*Back neck depth*, *front neck depth* and *front neck width* are proportions of the neck base girth, and are explained in the instructions.)

8 Shoulder
Tie a fine tape around the neck, let it find its lowest level. Measure from this tape to the acromion (bone at the end of the shoulder).

9 Upper arm girth
Measure around the fullest part of the bicep, fairly generously.

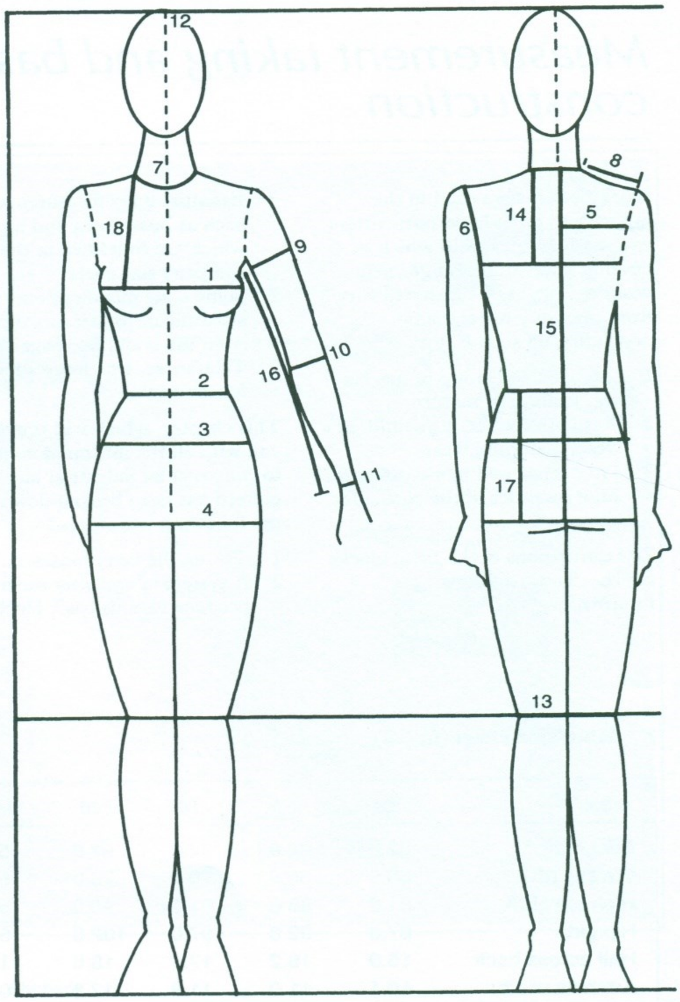
10 Elbow girth
Measure around the elbow, using the elbow as a guide, fairly generously.

11 Wrist
Use the bones at the wrist as a landmark. Measure fairly generously.

12 Height
From the top of the head to the ground. The model must take off her shoes.

13 Dress length (to knee)
Measure from the nape of the neck to the knee.

3



14 Armhole (or scye) depth
A very difficult measurement to calculate as there is no real landmark. This measurement also depends on fashion. You are advised to use the size chart for an average.

15 Nape to waist
Locate the nape, or seventh cervical vertebra. Measure down to waist tape.

16 Underarm length
Position the tape measure to the highest point of the underarm and measure down the underarm to the wrist bone. To allow for movement reduce this measurement by 3 cm.

17 Waist to hip
Measure down from waist tape to the hip bone.

18 Nape to bust point
This is an important measurement which affects the hang of the garment. Measure from the nape at centre back (CB) around the back neck through the front shoulder neck point down to the bust point. Note that the height of the bust point will depend on whether a bra is worn.

11.1.10 Joseph-Armstrong, (2009)

HORIZONTAL ARC FOR FORM AND MODEL MEASUREMENTS

Front

Figure 6

- *Across shoulder (14).* Shoulder tip to center front neck.
- *Across chest (15).* Center front to mid-armhole level (pinhead mark).
- *Bust arc (17).* Center front, over bust point, ending 2 inches below armplate at side seam.
- *Bust span (10).* Place tape across bust points; divide in half for measurement.
- *Waist arc (19).* Center front waist to side waist seam.
- *Dart placement (20).* Center front to side front (princess line).
- *Abdomen arc (22).* Center front to side seam, starting 3 inches down from waist.
- *Hip arc (23).* Center front to side seam on HBL line.
- *Hip depth (25).* Center front to HBL line.

Figure 6

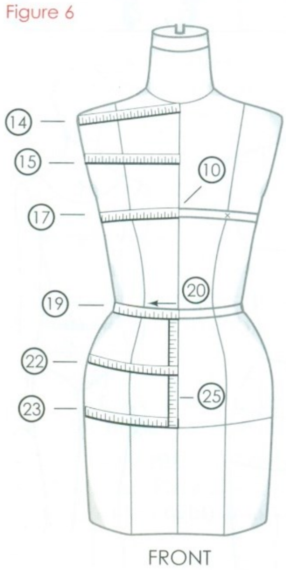
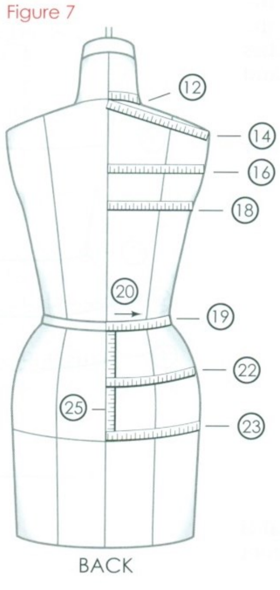


Figure 7



Back

Figure 7

- *Back neck (12).* Center back neck to shoulder at neck.
- *Across shoulder (14).* Shoulder tip to center back neck.
- *Across back (16).* Center back to the mid-armhole level at ridge of pinhead.
- *Back arc (18).* Center back to bottom of arm plate.
- *Waist arc (19).* Center back waist to side waist seam.
- *Dart placement (20).* Center back waist to side back (princess line).
- *Abdomen arc (22).* Center back to side seam, starting 3 inches down from waist.
- *Hip arc (23).* Center back to side seam on HBL line.
- *Hip depth (25).* Center back waist to HBL line.

Model for Personal Fit

Figures 8a, b

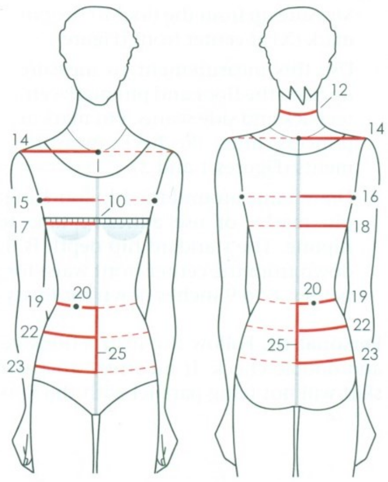


Figure 8a Figure 8b

Measurements can be taken across the model from one landmark to the other, then divided in half and recorded. If the center lines of the front and back are definitely centered, measure from the center line to the side seams of the front and back bodice.

Neck Circumference

Measure around the upper neck, divide 4 3/4", or use the chart measurement.

VERTICAL MEASUREMENTS FOR FORM AND MODEL

Figures 9 and 10

- *Side length (11).* Pin mark below armplate at side seam to side waist.
- *Shoulder length (13).* Shoulder tip to neck.
- *Side hip depth (26).* Side waist to HBL, on side of form being measured.
- *Bust radius (9).* Measure from bust point ending under bust mound to rib above.

Front and Back—Form and Model

Figures 11, 12, 13, 14

- *Center length (5).* Measure neck mark to waist (over bridge).
- *Full length (6).* Waist to shoulder at neck, parallel with center lines.
- *Shoulder slope (7).* Center line at waist to the shoulder tip (mark).
- *Bust depth (9).* Shoulder tip to bust point.

Figure 11

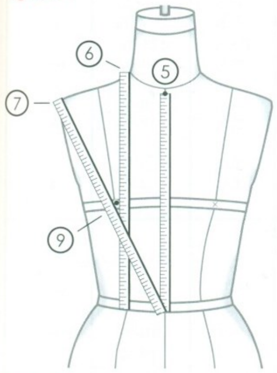


Figure 13

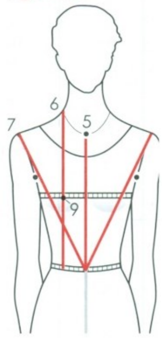


Figure 12

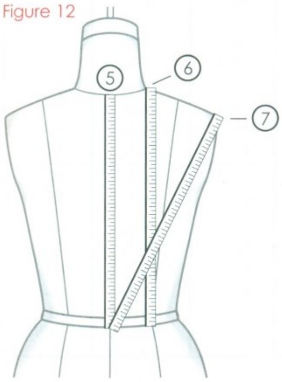


Figure 14

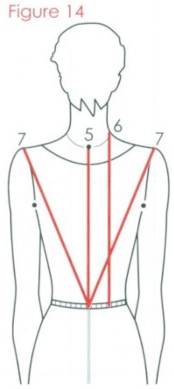


Figure 9

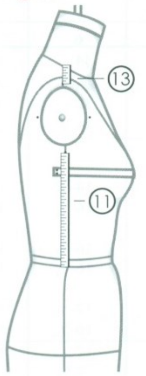
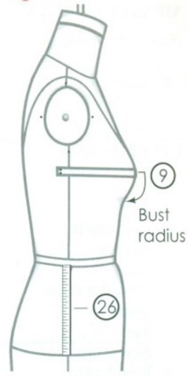


Figure 10



Personal Fit: Asymmetric Verification

Shoulder slope: Measure on right and left sides. If the slope measurements differ more than an 1/8 inch, the shoulders are asymmetric.

Side hip: Measure both side (see #26), if measurements differ more that 1/8 inch, the hip is asymmetric. The patterns will be drafted on folded paper and discussed later.

Figure 15 and 16: New Strap Measurement

New Strap (8). Place metal tip of the measuring tape at corner of shoulder/neck to bottom of the waist band at the side seam and record.

Figure 15

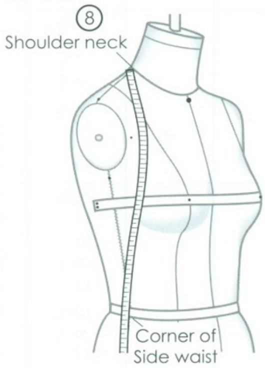
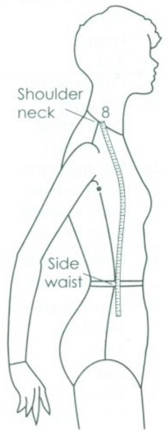


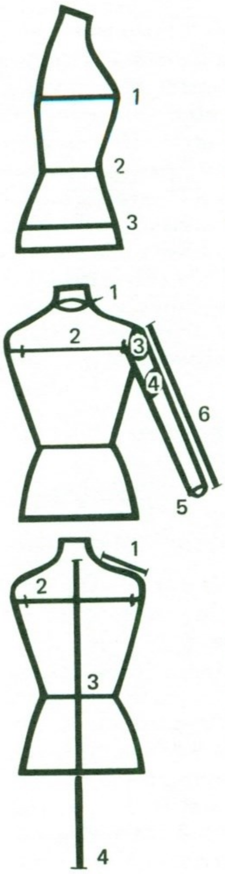
Figure 16



11.1.11 Stanley, (1975)

Metric Size Chart

Based on the average figure of average height of 164–169cm



Size	36	38	40	42	44
To fit in centimetres	10	12	14	16	18
Bust	84	88	92	96	100
Hips	90	94	98	102	106
Finished Measurements					
1 Bust	94	98	102	106	110
2 Waist	62	66	70	74	78
3 Hips (20cm down from waist)	95	99	103	107	111
Front & Arm Measurement					
1 Neck girth	35·5	36·5	37·5	38·5	39·5
2 Across chest (10cm from pit of neck)	34	35	36	37·5	39
3 Armhole circumference	41	42	43	44	45.5
4 Upper arm girth	32	33	34	35·5	37
5 Wrist	19·5	20·5	21·5	22·5	23·5
6 Sleeve length	58	58·5	59	59·5	59·5
Back Measurements					
1 Shoulder length	12·5	13	13·5	13·5	14
2 Across back (10cm from nape)	35·5	36·5	37·5	39	40·5
3 Nape to waist	39	40	41	41·5	42
4 Dress length (according to fashion)					

Seam Allowances

13mm to 2.5cm:

Side seams

Sleeve seams

Shoulder seams

6mm

Neck line

Collars

Facings

13mm:

Waist

Sleeve Head

Armhole

Panel lines

xiii

11.1.12 Kunick (1984)

MEASURING TECHNIQUE, MEASUREMENTS AND SIZES

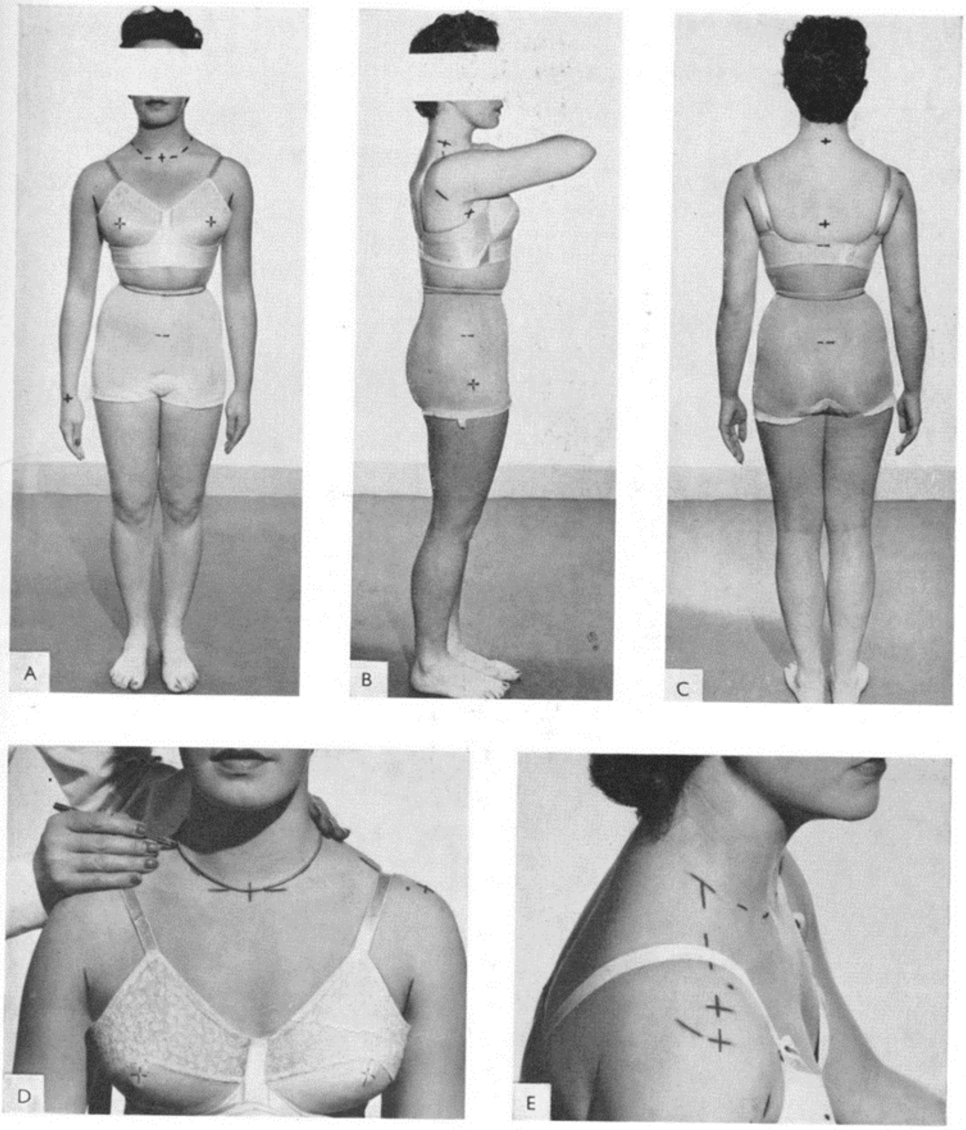


Plate 1

A, Landmarks on the front of the body; B, Landmarks on the side of the body; C, Landmarks on the back of the body; D, Position of neck chain on the base of the neck; E, Landmarks used in locating the shoulder points and armscye.

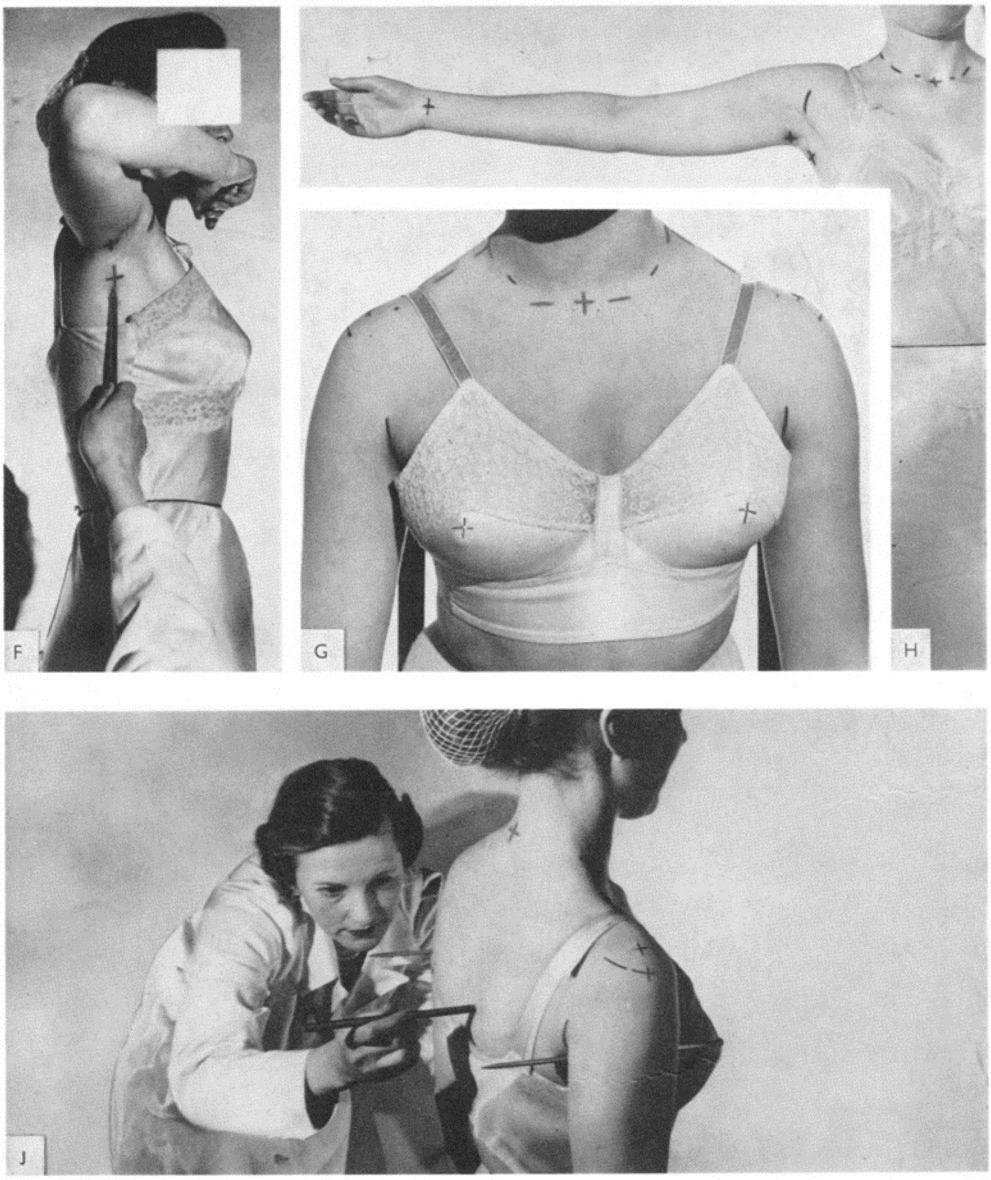
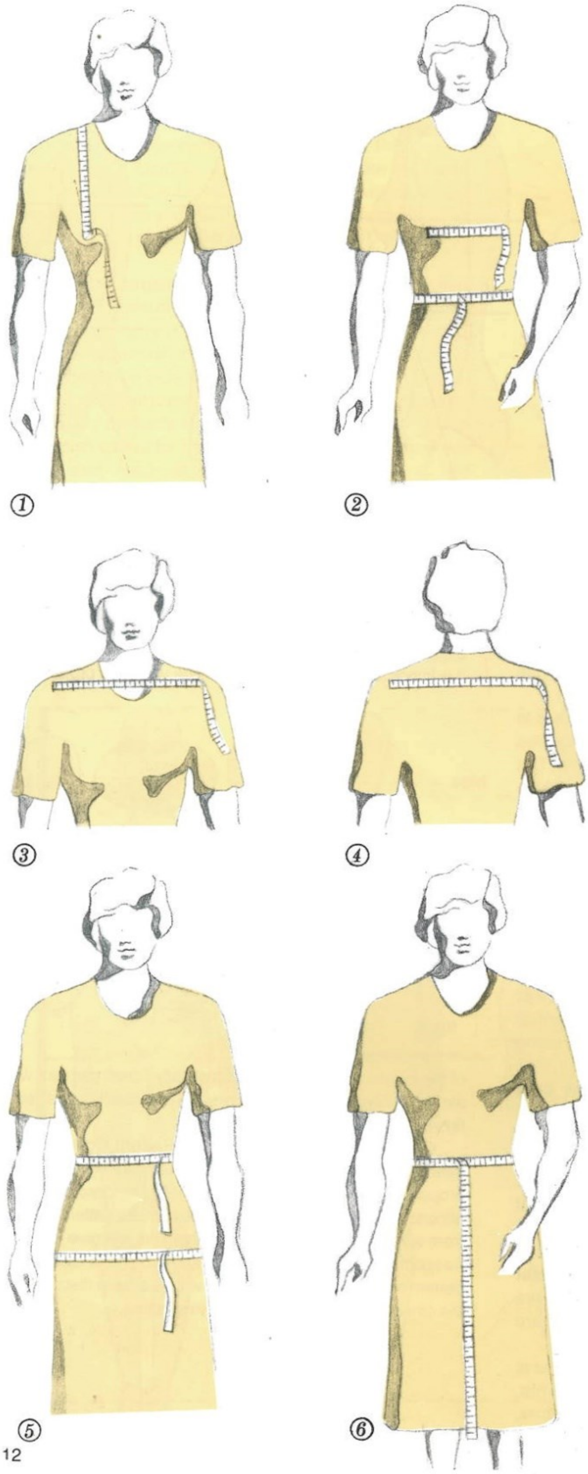


Plate 2

F, Locating the underarm midpoint; G, Landmarks on the front of the upper portion of the trunk; H, Underarm midpoints on trunk and arm; J, Locating the Depth of scye.

11.1.13 Vouyouka, (1996)

MEASUREMENTS FOR THE FITTED BODICE AND DRESS BLOCKS



12

• Besides the Simple Bodice Block there is the Fitted Bodice Block. These two pattern pieces stop at the waist. The Fitted Bodice Block includes darts at the shoulder and the waist by which the lines of the body are smoothly followed. This block forms the basis for all garment patterns because, by dart manipulation ,any design can be achieved. This is the most crucial factor for garment design whatever the fit.

• There is also the Fitted Dress Block which combines the Fitted Bodice and Skirt

• To make these two blocks, besides the measurements that you already have, the following are also needed:

Bust Length (B.L.)

• Measure vertically from the shoulder to the most prominent bust point.

Bust Distance (B.D.)

• Measure the distance from one bust point to the other. Use half the measurement (fig. 2)

Shoulder Distance (front) (S.D.)

• Measure, as in the figure, from each shoulder bone. (fig. 3)

Shoulder Distance (back) (S.D.)

• Measure, as the figure, from each shoulder-blade. (fig. 4)

Waist Measurement (W.M.)

• Measure the waist where it is slimmest. When you measure for a skirt or trousers take an exact measurement, when you measure for a dress take it looser (fig. 5)

Hip Measurement (H.M.)

• Measure hips at the most prominent point, taking care that the tape measure rests at an even level, to avoid getting an awkwardly full pattern. (fig. 5)

Skirt length (S.L.).

• Measure from the waist to the desired length. (fig. 6).

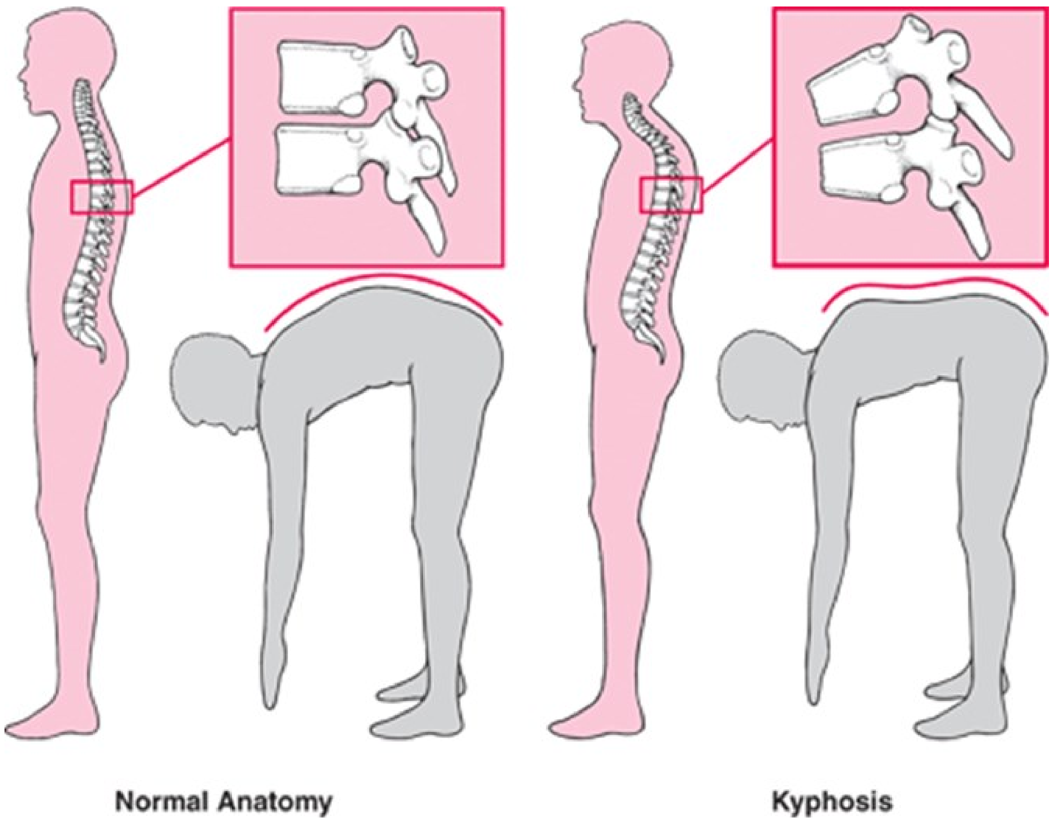
12 Appendix D

12.1 Manual Anthropometric measuring equipment

Thehumansolutions.com, (2016)

13 Appendix E

13.1 Kyphotic Posture and wedge angling of the spinal segments



Source: Kyphosis (Pessler & Sherry, 2008)

14 Appendix F

14.1 Comparison of Flat Pattern Drafting Methods

Flat Pattern Drafting Methods					
Method	**Number of body measures for a bodice**	**Guidance for alternative body morphologies**	**Proportional measurements**	**Direct measurements**	**Observations**
Beazley & Bond (2003)	13	Yes both in the method and as re-engineering.	1 (Neck girth)	12 (Bust, waist, neck, back neck rise, nape to waist, armhole depth, front neck point to bust point, front neck point to waist, X back, X front, shoulder, width of bust prominence, width of armhole)	Side neck over bust to waist good for large bust. Does not use X chest even though it asks the practitioner to take it.
Joseph-Armstrong (2010)	22	Yes both in the method and as re-engineering.	6 (dart length, depth and placement, X chest depth, X back depth)	16 (side neck point to waist, X shoulder, CF length, bust arc, shoulder slope, bust depth, shoulder length, bust span, X chest, front dart placement, side neck poin to side seam, underarn point to waist, waist	Geared towards the predetermined size chart. No direct armhole measurements

				arc front, centre back finishing at armpit point, centre back neck to shoulder, centre back to mid armhole)	
Aldrich (2008)	11	Yes only in later chapters	4 (Neck girth, shoulder angle, dart placement, horizontal and vertical measurements surrounding and shaping the armscye)	7 (armscye depth, bust, nape to waist, waist to hip, shoulder length, X back, X chest)	No bust prominence, no bust point length. Bust point based on garment measurement (2.5cm from underarm point).
Bray	7	No	Shoulder line, X back depth, neck girth	Waist, bust, shoulder length, X back width, X chest width,	Geared towards the predetermined size chart. No over bust measurement. Hip depth is set at 22cm below the waist; bust point height is set at 2.5m below the armpit. Has predetermined size chart, which encourages

					the practitioner to use.
Abling (2009)	18	No	7 (Side seam placement, armscye shaping, shoulder angle, CB length, Bust point height, neck girth), half bust circumference	8 (Shoulder length, CF length, bust, waist, bust to bust, X back, X front chest, side neck point front and back to waist, front waist to shoulder point), CF neck to bust level,	Vague regarding bust prominence, level. Predetermined size chart. Asks for a number of measurement and then does not use them.
Vouyouka (1996)	5	Yes in later chapters	(Waist, bust to bust, bust length, should distance, shoulder distance front and back, These measurements are based on proportions of the bust or chest.	Bust or chest girth	Initially asks for a number of body measurements for the bodice draft. Does not ask for bodice length but this is a required length for drafting the block.
Haggar (2004)	6	No	Underarm point, under arm height, X back height, Neck girth, shoulder slope, X chest height, side seam, dart placement and width.	Nap to waist, bust, X back width, shoulder length, bust to bust, X chest width,	Adds on to waist length to account for bust prominence. Armscye measurements uses divisions of other measurements .

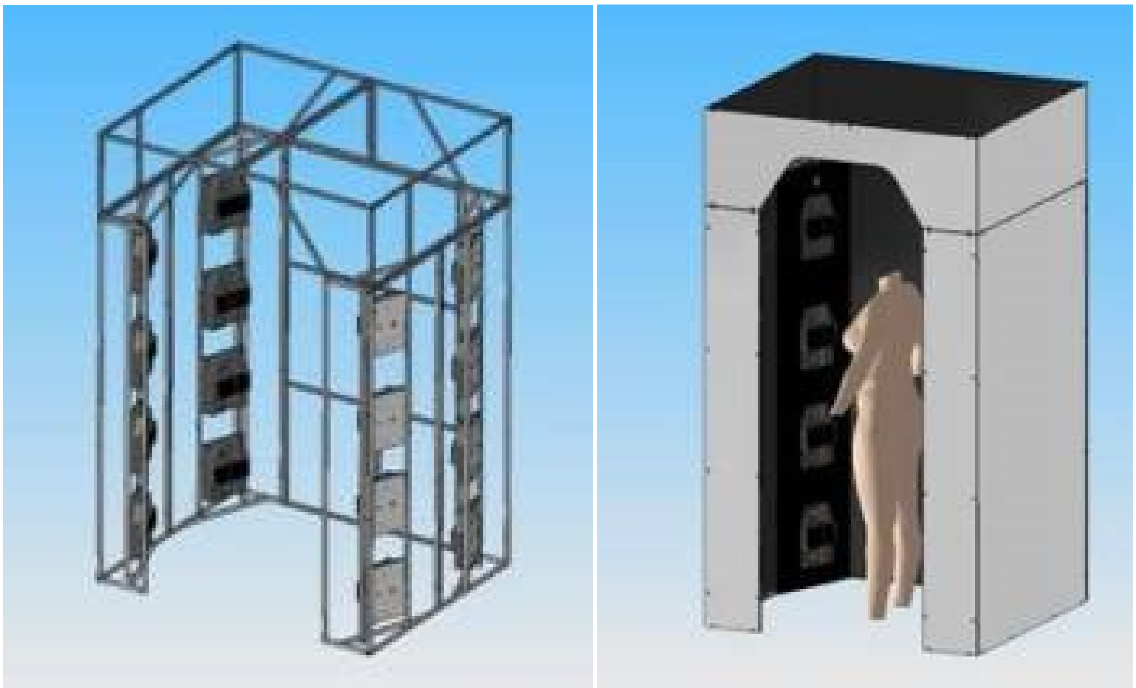
Knowles (2005)	10	No	Side seam length, shoulder slope, neck girth,	Shoulder seam, CF neck point to tip of shoulder, bust level, CF length, shoulder tip to CF waist level, waist level, bust span, waist, side neck point to side seam marked at the underarm point. Shoulder tip to apex	Some measurement such as shoulder seam, dart placement relate to clothing more than the anatomy. Does recommend measuring older participants. Measures over a leotard and landmarks using pins and tape, similar to marking out the stand for modelling. Tries to interpret the side seam placement using the stand. Side neck over bust to waist good for large bust.
Chunman-Lo (2011)	13	Yes in later chapters	Armhole depth, armhole girth, side neck point to mid front armscye, side neck point to mid back armscye, side neck point over bust to waist,	Bust, CB neck to waist, waist, front X shoulder, back X shoulder, shoulder length,	Works from a predetermined size chart. Recommends dipping the front bodice to account for a large bust. Using some garment points

			side neck point over shoulder blade to waist, neck circumference,		of measurements as landmark definitions. Discusses front and back bodice portions. Takes segment length starting from nape of neck.
Bunka (2009)	3	Yes in later chapters.	Neck girth, shoulder angle, underarm point, armscye girth, chest width, X back width, chest height, shoulder angle, shoulder length	Bust, waist, CB length	Most comprehensive list of body measurements but has the least amount of body measurements for basic bodice construction.

15 Appendix G

15.1 The three light-based technologies used in 3D body scanning technology

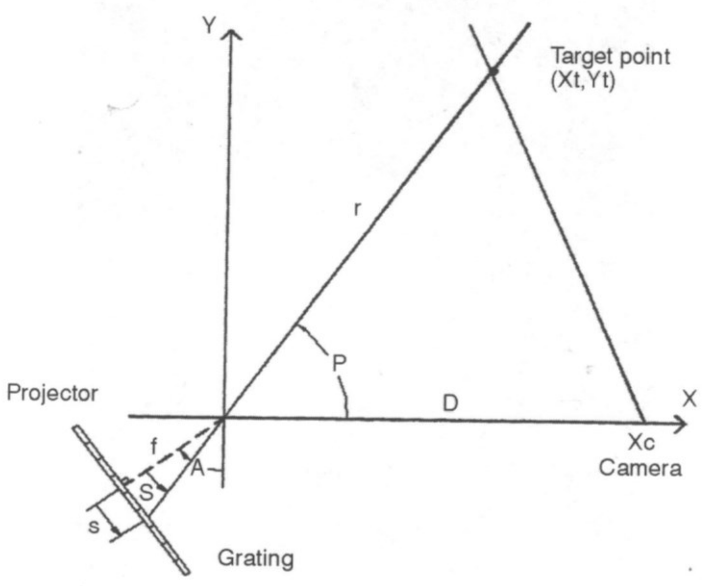
15.1.1 White light based body scanning technology



Sensor and light configuration (Derners, 2008)

Example of a sensor and light unit (Derners, 2008)

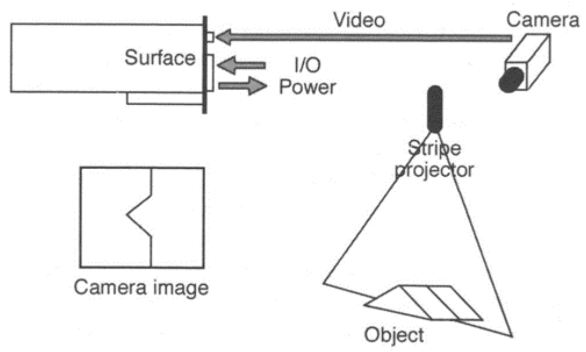
TC² gridded light pattern (Derners, 2008)



Schematic illustrating hardware configuration and image capture theory for phased or white light based scanning technology (Fan *et al*, 2004, 152)

15.1.2 Laser light-based 3D bodyscanning technology

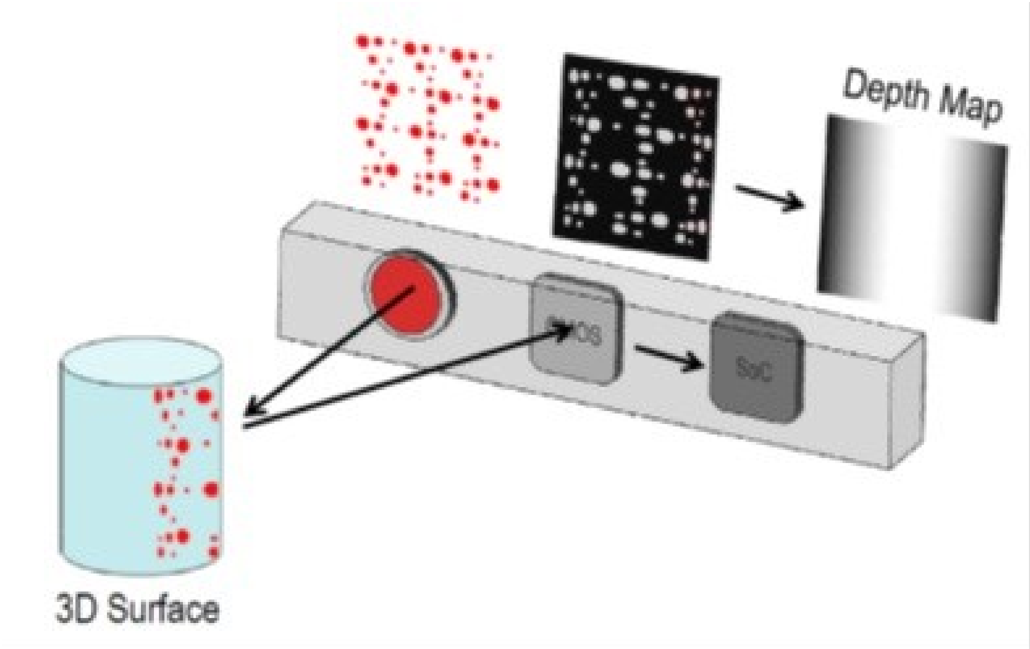
The laser scanning booth (Humansolutions.com, 2016)



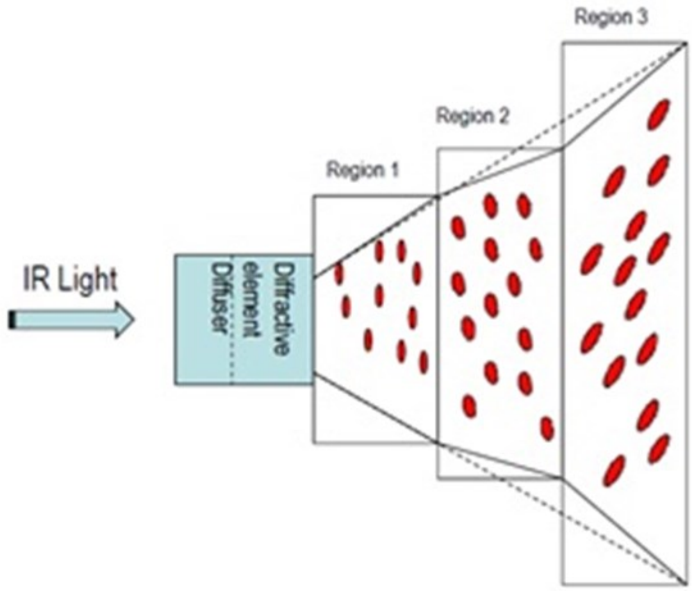
Schematic illustrating hardware configuration and image capture theory for laser based scanning technology (Fan et al, 2004, 154)

15.1.3 IR (Infra-red) light-based 3D bodyscanning technology

Example of the TC² KX16 scanner configuration (Fashiontechwordpress.com, 2012) This scanner uses Microsoft Kinect Technology



Kinect sensor configuration (Depthbiomechanics.co.uk, 2016)



The Kinect's DOE and associated speckle output (Depthbiomechanics.co.uk, 2016)

Speckled IR light over the skin surface (gmv.cast.uark.edu, 2016)

16 Appendix H

16.1 Survey of 3D bodyscanning hardware and software

Scanner Hardware and Software Overview

Proprietary Scanner	Technology	Software	Limitations	Size and purpose of scanner	Hardware configuration	Used in which surveys	Contact	Ref
3D Digital Corporation **Has models from Optix 400 H to 400 S. The higher the letter the better accuracy and resolution (3ddigitalcorp.com, 2009).**	Laser from Optix 400 H to 400 S	Escan software produced by 3D Digital Corporation (3ddigitalcorp.com, 2009) Merges & aligns scans together. Allows 3D viewing. Appearance and colour can be adjusted. Scales and takes basic measurements. Allows point cloud and mesh formats to be exported (3ddigitalcorp.com, 2009).	Takes only basic measurements, the larger the scan the lower the accuracy or resolution (3ddigitalcorp.com, 2009).	Portable (3ddigitalcorp.com, 2009)	Uses the principles of laser triangulation. By making a triangle between the scanner lens, laser, and object being scanned 3D data is obtained (3ddigitalcorp.com, 2009). Speed of scan not discussed. Data is processed with the software SLIM 3D by 3D-Shape (3ddigitalcorp.com, 2009).	Used by podiatrists, dentists, forensics, automotive industry and museums artefacts. Company customises its scanners (3ddigitalcorp.com, 2009). NOT USED FOR ANTHROPOMETRIC SURVEYS AS YET.	http://www.3ddigitalcorp.com/3d-laser-scanner.shtml sara@3ddigitalcorp.com	**Contact:** (Showing All)
ABW	White light ABW 3D LCD-320 and two CCD-cameras (abw-3d.de, 2009)	**ABW 3D software** ABW-3D is a dynamic link library (DLL). It is written in object oriented manner in C++. You may integrate it in an existing visual system. It is hardware-independent and makes no graphical output. Your system keeps complete control of the graphical user interface. ABW-3D just gets the images from your system and returns the results (abw-3d.de, 2009).	Only scans small sections, can lose areas because of the method of scanning (abw-3d.de, 2009).	Small scanner not whole body.	One projector and two cameras (abw-3d.de, 2009).	Face scanner NOT USED FOR ANTHROPOMETRIC SURVEYS AS YET.	ABW GmbH Siemensstraße 3 D-72636 Frickenhausen info@abw-3d.de	abw-3d.de, (2009)

5	**Arius 3D**	Laser **Arius 3D** Consists of a laser scanner and a motion control system for moving the camera (scanner is small) (arius3d.com, 2009).	Pointstream 3D Image Software Comes with Pointstream capture and image processing software (arius3d.com, 2009). Creates a create a polygonal surface approximating the digitized point cloud (arius3d.com, 2009). The Pointstream method takes scanned 3D data directly into rasterization (arius3d.com, 2009). Images can be scaled, viewed in colour (arius3d.com, 2009).	Has not so far been used for living subjects (arius3d.com, 2009). Unsure if laser is eye-safe.	Colour laser scanner in RGB mode (arius3d.com, 2009). No information regarding speed of data capture.	System characterises each measurement point according to its colour and location in 3D space using the principles of high resolution, low-noise, three-colour laser triangulation and optically synchronised scanning (arius3d.com, 2009).	No surveys mainly used for museum artefacts (non-living objects).	Arius3D Inc. 755 The Queensway East, Unit 20 Mississauga, Ontario Canada L4Y 4C5 Tel: 905-270-7999 Fax: 905-270-6888 info@arius3d.com.	arius3d.com, (2009)

6	**Breuckmann**	White light bodySCAN 3D (4) Consists of a projector and 2 digital cameras (breuckmann.com, 2009). Colour scans come as an additional optional extra in the form of high resolution 1384 x 1036 pixel colour CCD cameras (breuckmann.com, 2009).	OPTOCAT software used with window XP (breuckmann.com, (2009) the OPTOCAT software can perform triangulation calculation to measure the position of each point within the fringe pattern. Because of the way the system works, it can scan millions of points within a few seconds (Daanen, , & Jeroen van de Water, (1999). Will export into the following formats ASCII, STL, PLY or VRML (breuckmann.com, (2009). The software offers an easy-to-use graphical user interface(D'Apuzzo, 2005).	Open scanner not private, though can scan larger objects or more than one person at a time (Daanen, , & Jeroen van de Water, 1999).	Various sizes of scanner. Data capture in 2.5-4.5 seconds (breuckmann.com, 2009). Has high resolution because has 8 cameras in total (breuckmann.com, 2009).	It has four measuring columns, each equipped with a projector and two digital cameras (breuckmann.com, 2009). All of the products rely on a technology called Miniaturised Projection Technology (MPT), itself based on structured white light scanning. This patented MPT device projects a moiré fringe pattern on the object being scanned. This is .then captured using the camera unit (D'Apuzzo, (2005).	Scanned the German national football team in 2006 (breuckmann.com, (2009) Has the ability to capture the complete geometry of the body, even in dynamic positions (Daanen, , & Jeroen van de Water, 1999) .	secretary@breuckmann.com Dr Bernd Breuckmann, Alexander Poledna. (++49 / (0)7532 / 4346 0)	breuckmann.com, (2009) , Daanen, , & Jeroen van de Water, (1999), D'Apuzzo, (2005)

	Cyber F/X	Laser **CYBER F/X 3D**	Scanning software is proprietary but not discussed on the companies site as they are selling scanning services and not scanning equipment. The scans are linked to proprietary sculpting equipment for rapid prototyping (Cyber F/X.com, 2009).	Scanning facility open and not private.	Large open VFX staging area. This company claims to have the largest mobile 3D body scanning equipment in the world (Cyber F/X.com, 2009). Described as "rapid 3d laser scanning" (Cyber F/X.com, 2009).	Consists of a platform surrounded by four optical heads on metal supports (Cyber F/X.com, 2009).	Used in the movie industry to scan actors for special effects purposes (Cyber F/X.com, 2009).	info@cyberfx.com	Cyber F/X.com, (2009)
7	**Cyberware**	Laser Can give colour scans (Cyberware.com, 1999). **Model WBX** Whole Body Color 3D Scanner takes hundreds of thousands of measurements of the human body in just 17 seconds. Four scanheads collect high-speed 3D measurements every 2 mm from head to toe to create an accurate 3D data set (Daanen, & Jeroen van de Water, 1999)	**CyScan** Cyberware's own proprietary software. This software allows the viewer to view the scan as a point cloud as the default setting and also as Gouraud shaded, RGB color shaded, or shaded and texture surfaces (Cyberware.com, 1999). The software can be uploaded onto any pc and allows the user to save files to a TIFF format (Cyberware.com, 1999). This format can also be used with AutoCAD, Surfacer, 3D Studio, Power Animator, Maya, Softimage, and others (Cyberware.com, 1999).	Can scan dark clothing. Is less susceptible to missing point cloud data at areas like the underarm or crotch (Cyberware.com, 1999).	Fully enclosed unit. Designed for heavy use and can scan one subject per 30 seconds (Daanen, & Jeroen van de Water, 1999). Scans in 17 seconds (Daanen, & Jeroen van de Water, 1999).	Four scan heads collect high-speed 3D measurements every 2mm from head to toe. Works with Optitex 2D and 3D CAD/CAM solutions (Cyberware.com, 1999).	Used in the following surveys and research: CAESAR (Daanen, & Jeroen van de Water, 1999)	Cyberware, Inc. 2110 Del Monte Avenue Monterey, California 93940 USA info@cyberware.com	Cyberware.com (1999), (Daanen, & Jeroen van de Water, 1999)

9	**Cyberware Model WB4**	Laser. Can give colour scans (8).	Also uses **CyScan** software. **The software extracts measurments automatically although it will allow interaction (Kirchdörfer, & Rupp, 2006). The landmarking is automatic but will partly allow interactive modifications (Kirchdörfer, & Rupp, 2006).**	Scanning facility open and less private.	Can scan larger subjects, not unlike the Cyber F/X. Scans in 17 seconds (8).	Four scanning instruments mounted on two vertical towers. Scanning instrument moves vertically. Subject stands on platform, while a separate frame provides alignment for the towers. Scanning instruments start at the head and moves down to scan the entire body. Can scan larger objects in different positions (8).	Has been sold to USA (the CARD-lab at Wright Patterson Air Force Base, the National Institute of Occupational Safety and Health (NIOSH) and the Army Research Labs in Natick) and one in Japan(9)	Cyberware, Inc. 2110 Del Monte Avenue Monterey, California 93940 USA info@cyberware.com	Kirchdörfer, & Rupp, (2006), Daanen & Jeroen van de Water, (1999)

10	**Digibotics DIGIBOT II 3D Laser Digitizer** **(Unsure if this company is still trading)**	Laser	No information available	Unsure if eye-safe as was served with a warning letter from the dept of health & human services in 2000 stating concerns about the lasers (24).	Small scanner	A focused laser beam moves across the object as the object revolves on a turntable. It uses this single point of light and a triangulation algorithm to measure the exact x and y co-ordinates of each point on the surface of the specimen at a fixed z co-ordinate or level.	Used for the scanning of bone artefacts at the Department of Anthropology, The University of Texas (1999).	Kim Carpenter Digibotics 2800 Longhorn Blvd. Suite #104 Austin, Texas 78758	Spears, (2000),
11	**GOM**	White light **Atos scanner** (Gom.com, 2009).Can scan dark and light objects at the same time. Can scan objects with shiny surfaces (Gom.com, 2009). Measures areas hidden to the cameras using an optical probe though unsure if it is used for face scanning (Gom.com, 2009).	**Atos proprietary software (Gom.com, 2009).** Can be uploaded onto a pc (Gom.com, 2009). Will measure objects and allows measurements to be viewed in tabulated format (Gom.com, 2009). Generates polygon mesh on the scanned object (Gom.com, 2009). Can edit polygon mesh, smoothing surfaces and filling in holes in the data (interpolation) (Gom.com, 2009). Saves files in common file formats (Gom.com, 2009).	Face scanning only.	Small scanner for face.	Based on the principle of triangulation. Fringe patterns are projected onto the object's surface with a white light projection and are recorded by two cameras (Gom.com, 2009).	Used for the automotive industry, medical artefacts etc.	Business Innovation Centre Harry Weston Road, Binley, Coventry, CV3 2TX United Kingdominfo-uk@gom.com	Gom.com, (2009)

12	**Hamamatsu Bodyline Scanner C9036 (jp.hamamatsu.com, 2008)**	LED, infrared light.	Automatic labeling software trunk homologous modeling software of private marker seal marker position automatic detection software marker (https://www.dh.aist.go.jp/database/fbodyDB/, 2003). Softwear creates mesh images. **Software for measurement is Automatic and interactive and although landmarking is automatic is will allow partial interaction Kirchdörfer, & Rupp, (2006).**	Large scanning booth 275x159x167 Not a colour scanner.	Whole body scanner. Scans in 7 seconds	Has photodiodes which are sensitive to infrared light (Daanen & Jeroen van de Water, 1999). According to Daanen & Jeroen van de Water (1999) The device has 8 projectors, and 8 cameras. It also scans from top to bottom and works with a PC.	Medical industry (sales.hamamatsu.com, 2009a) Clothing fit (Daanen & Jeroen van de Water 1999) Is eye safe. (email received from Kunihiko Tsuchiya 2/12/09, body scanner no longer in manufacture and no plans for a replacement model)	2 Howard Court, 10 Tewin Rd, Welwyn Garden City, Herfordshire AL7 1BW Email infor@hamamatsu.co.uk	Kirchdörfer, & Rupp, (2006), Daanen & Jeroen van de Water, (1999)
13	**Hamano**	Slit light laser (Daanen & Jeroen van de Water, 1999) **Voxelan HEW-1800HSW**	**Voxelan proprietary software**. Imports scan data and supports 3D visualisation. **Extracts measurements and user can interface with system and extract specific measurements (Daanen & van de Water, 1999), althougha more recent study by Kirchdörfer, & Rupp, (2006) indicates there is no information if the system allows interaction regarding landmarking or measruement extraction.**	Uses JIS or ISO standards for landmark definition although will allow database interface using subject type builder within the system (Voxelan.co.jp, 2009)	Is a large curtained booth. Scans in 10-60 seconds/all round (variable) (Voxelan.co.jp, 2009)	Uses DT viewer softwear to view scan data (Voxelan.co.jp, 2009). 8 CCD cameras. Uses a montage of images to make up 3D scan image.	Eye safe (class 2) (Voxelan.co.jp, 2009) Used for anthropometrical data gathering (Daanen & Jeroen van de Water, 1999). Owned by many Japanese research and educational institutions.	info@voxelan.co.jp phone 00 81 44 819 2168 Have registered with them already for literature (1 Dec 2009).	Voxelan.co.jp, (2009), Daanen & Jeroen van de Water, (1999), Kirchdörfer, & Rupp, (2006)

Human Solutions	Laser Anthro-scan **Vitus Smart XXL** **TecMath** Scanner	ScanworX software Allows visualisation of the scan and extracts measurements (human solutions.com, 2000). Scans in colour. **Automatic and interactive measurment extraction and landmarking is also automatic or interactive allowing individual modifications Kirchdörfer, & Rupp, (2006).**	Pre set with ISO 7250 and ISO 8559) standardised body dimensions Large booth (eye safe)	Whole body Scanned in 12 seconds Will scan different body positions. Allows interactive measurement rules (Humansolutions.com, 2009a)	Four column scanner based on the optical triangulation procedure with 8 sensor heads (Humansolutions.com, 2009a)	Size Germany CAESAR (Netherlands) Quatar armed forces measurements survey TecMath scanner also used for Chan et al (2005) research Also used by Honey & Olds (2007) in their research the quanitfication of the mismatch into the standards of the Australian sizing system.	contact@human-solutions.de	Chan et al, (2005), Humansolutions.com, (2009a), Honey & Olds, (2007), Human solutions.com (2000), Kirchdörfer, & Rupp, (2006)

15	**Inspeck**	White Light **3D Mega Capturor II** the digitising box has one camera and halogen light. Sits on a vertical tract stand and can move vertically along it.	Proprietary software called **EM**. Software for obtaining measurments is partly interactive and partly automatic (Kirchdörfer, & Rupp, 2006 . Sofetawre has following features: Opening and viewing 3D models Smoothing Polygon cleanup and simplification Registration Merging 2D/3D texture editing Hole closing Data interpolation tool 3D model editing Import formats (OBJ, FBX) Exports to most formats User-friendly interface (Inspeck.com, 2009). **Interactive and automated measurement extraction and landmarking is interactive (Kirchdörfer, & Rupp, 2006).**	To keep the processing time down three digitizing units are needed which raises the cost of the system as they are bought singulaly (Inspeck.com, 2009).	Can scan hair (Inspeck.com, 2009). It is a portable digitising system enclosed inside a retangular box (similar to the KomicaMinolta system).	Works on the principles of triangulation (Inspeck,com, 2009)	No surveys (Kirchdörfer, & Rupp, 2006)	info@inspeck.com	Kirchdörfer, & Rupp, (2006), Inspeck.com (2009),

Intellifit Corporation	Radio Waves or millimeter wave technology Intellifit VFR Hardware works by a wand rotating around the person. This wand is stored inside a fitting booth (intellifit,Uniquesscan.com, 2008)	Intellifit software then electronically measures the "point-cloud", producing a file of dozens of accurate body measurements; the raw data is then discarded (intellifit.Uniquesscan.com, 2008). **Automatic measurement extraction, no published information at present as to how the system marks body landmarks (Kirchdörfer, & Rupp, 2006).**	Low resolution scans.	Whole body scanner. Scanned in 15 seconds. Works with the base line energy emitted from a human body.	Uses a vertical wand containing 196 small antennas that send and receive low power radio waves. The radio waves send and receive low power signals. The signals don't "see" a customer's clothing but reflect off their skin. The signals are similar to mobile phone signals but less than 1/350th of the power and they do not penetrate the skin. When the wand's rotation is complete, Intellifit has recorded over 200,000 points in space, x, y, and z coordinates of where the subject is standing. The software then electronically measures the point-cloud, producing a file of dozens of accurate body measurements; raw data is then discarded.	Has been used in conjuction with other computer software applications to provide individual body measurments and recommendations of best fit sizes (availabletechnologies.pnl.gov, 2008). Has been used by Levi Strauss, CHARMING SHOPPES, INC and Alvanon Incorporated (intellifit.Uniquesscan.com, 2008).	webfeedback@intellifit.com	intellifit.Uniquesscan.com, (2008), availabletechnologies.pnl.gov, (2008), intellifit.Uniquesscan.com, (2008).

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17	**Leica C10 Scan Station**	The Leica C10 Scan Station scanner is a time-of-flight scanner with an effective operating range of +/- 1-200 m (up to 300 m with 90% reflectivity). It's motorized head allows scanning of a complete 360 degree by 270 degree area.	Data is acquired at a rate of 50,000 points/second and can be stored on-board or on a wireless or wired laptop.The data acquired by the systems is processed using various software including Cyclone, Cloud Worx (a series of plug-ins for CAD software), PolyWorks, and Rapidform.	Not with a private booth. Not designed for scanning people.	Is a tripod based piece of hardware normally used to document large outdoor spaces and landscapes.	Time of flight. laser light technology.	The C10 scanner played a key role in the precise 3D mapping of the Greco-Roman structures at Karanis in the Fayum of Egypt as part of the UCLA's Fayum Project.	http://gmv.cast.uark.edu/scanning-2/hardware/leica-c10-scan-station/	gmv.cast.uark.edu, (2016)

18	**Minolta Konica**	Laser, Galvanometer-driven rotating mirror (konicaminolta.com, 2009). **VIVID 910** (known as **V** in Europe) More recently Konica Minolta have developed a new scanner called **Konica-Minota Vivid 9i (gmv.cast.uark.ed 2016)**	proprietary Polygon Editing Tool (PET) Controls the hardware enabling scanning. Software generates polygon mesh, will edit, and convert the data into several common data formats. Multiple scans can be easily registered and merged into a single polygonal model. Will smooth, fill holes and filter irregular polygons and noise.	Not suitable for whole body scans due to size. Equipment is heavy (Fukuda, 2009, Case study on the Konicaminolta.com website)	Portable Scanned image in colour with measurements taken in 2.5 seconds (konicaminolta.com, 2009).	Triangulation light block method. Polygon-editing software is included with this product as a standard accessory (konicaminolta.com, 2009).	Kao's Anti-aging Research, Tokyo. Subject's faces were scanned to assess the extent of skin wrinkling and sagging in a variety of age groups. Contact Yukko Fukuda or Mayumi Satoh Biological Science Laboratories, Kao Corp. (Haga-gun, Tochigi, Japan. Also used by Cho et al, (2005) for their study on an interactive body model for individual pattern making.	101 Williams Drive Ramsey, NJ 07446 USA, Phone: Outside USA +1-201-236-4300	konicaminolta.com, (2009), Cho et al, (2005), Fukuda, 2009, (Case study on the Konicaminolta.com website)
19	**Polhemus**	Laser **Fastscan**	Delta software The interface allows the user to determine exactly where landmarks and regions of interest are placed. Measurements are gathered in PDF format by the user.	Scans only sections of the body. Is eye safe.	Information not found	Information not found	Used for dentistry and cosmetic surgery	40 Hercules Drive • PO Box 560 • Colchester, Vermont 05446-0560 US and Canada 800.357.4777 • 802.655.3159 • fax 802.655.1439 Polhemus.com	

20	**Size Stream**	Infra-red light and depth sensor technology. Microsoft Kinect Small portable tablet scanner will become available in early 2016.	Contains its own measurement extraction software.	Microsoft Kinect technology can mean resolution is lower than the alternative light source/image caputre technologies available.	Body scanning capabilities.	The scanner parts are housed in a rigid steel frame. Microsoft Kinect technology whereby the body is illuminated using IR (infra-red) light which is then picked up by depth sensors that record the distance from the light source to the solid surface	Used for anthropometric purposes.	Size Stream.com	Sizestream.com, (2014)
21	**Styku**	Uses a tower and revolving turntable to capture scans. Microsoft Kinect V2 technology. Technology is called **My Body**	Needs a Nvidia graphics card (superior graphics card which does not come as standard with all pcs). Can be used with tablet devices. Has its own measurement extration software.	configuration is not private	small footprint and is portable. Anthropometric purposes.	A tower with a camera and IR light source. A 360 degree rotating table/platform	Mainly used with in Gyms acording to its website.	info@styku.com	Styku.com, (2014)

TC2	White light **NX16,** Booth design which has 16 Sensors at independent 4 angles situated at 4 heights (hometrica, 2009). The **KX16** portable scanner	**NX16 Standalone V52.EXE** Controls the scanner hardware, generates measurements. Point clouds can be viewed in other formats. A personalised avatar is generated from the scan (hometrica, 2009). **Automatic landmark marking, allows interaction to the way the system extracts measurments (Kirchdörfer, & Rupp, 2006)**	Cannot scan subjects in any other posture other than standing anatomical due to the position, lights and cameras.	8 seconds scan duration. Markets itself as no larger than a changing room. KX16 has a lightweight portable frame to hold the light source and sensors. The outside of the frame can be covered if needed in a meade to measure sheath. Measurement definitions and printouts can be customized.	Uses projected white light and cameras to pick up the pattern of gridded light over the body surface. Stripes of light are measured from the body surface using triangulation (hometrica, 2009). The [TC]2 scanner obtains a cloud of raw photonic data points and then reconstructs the skin topography by using computer algorithms (Wells et al, 2007). The KX16 uses Microsoft Kinect technology whereby the body is illuminated using IR (infra-red) light which is then picked up by depth sensors that record the distance from the light source to the solid surface and back to the sensor.	SizeUSA, SizeUK, ShapeGB Senai Cetiq, Brazil Size Thailand Used to measure subjects for coast guard uniforms in 2008	dbruner@tc2.com 5651 Dillard Dr. Cary, NC 27518 USA	Fan, J., Yu, & W., Hunter, L., (2004), tc2.com, (2009), hometrica.ch, (2009), Kirchdörfer, & Rupp, (2006), Wells et al (2007). gmv.cast.uark.edu, (2016)

23	**Telmat Industrie**	White light **Symcad** Has stick on active landmark tracking markers which are wireless (Symcad.com, 2008). 4 digital video cameras inside a booth.	Has its own proprietary software **SYMCAD™ 3D digitizing** Automatically detects landmarks, Automatic extraction of more than 160 body measurements (compliant with ISO-8559 and ISO-7250 standards), Body shape analysis and automatic posture classification, Output file formats: VRML, IV, DXF, (3D data) - ORD, XLS, XML,(measurements). Works on a pc. 3D digitization in grayscale or in colors, quick 3D reconstruction. **Automatic and interactive measruement extraction, allows modification to landmarking (Kirchdörfer, & Rupp, 2006)**	Uses ISO-8559 and ISO-7250 standards for automatic landmark detection (Fan et al, 2004)	Booth design Fast, almost instantaneous (less than 2.5 seconds) so not affected by breathing or general body sway(Symcad.com, 2008).	Based on a 2D photographic method. Subject stands in the middle of the booth. A digital camera captures the front and profiles images of the silhouette. By tracing the outlines of the silhouette, the software calculates their dimensions, even allowing for posture (Fan et al, 2004, pg147)	Use by the French navy for improvements to uniform fit in 1995 (Fan et al, 2004). Also used by Nottingham Trent University in the late 1990's for research into human size and shape with direct relation to clothing manufacture (Fan et al, 2004).	6, rue de l'Industrie - B. P. 130 - SOULTZ 68503 GUEBWILLER Cedex (FRANCE) Tel. (+33) 383 54 80 76	Kirchdörfer, & Rupp, (2006), Fan, J., Yu, & W., Hunter, L., (2004)

The LASS system **According to Istook & Hwang (2001) one of the first of its kind.**	White light	No information found	Requires large floor space and is not private. It cannot accurately scan every part of the body and suffers from shadowing in the armpit and crotch regions of the body (Ulijaszek et al, 1998). Sac are large so precise location of measurement sights is difficult (Brook-Wavell et al, 1994).	Large open scanner, not private. Difficult to locate landmarks so landmarks located manually prior to scan. These landmarks are marked with adhesive cork markers which show up in the scan data (Brook-Wavell et al, 1994)	The subject is rotated so that the radii and angles of the body can be measured in conjunction with the height (Ulijaszek et al, 1998). Light is shone vertically onto the body from four different light sources (Ulijaszek et al, 1998). The light sources are pointed toward the central pivot point of the body and the centre of rotation on the table (Ulijaszek et al, 1998). The amount of light from its source to where it hit the body is recorded and the body radius is then calculated from this (Ulijaszek et al, 1998).	M&S, Bentwoods (M&S and Dunnes suppliers), Courtaulds lingerie, Kennett & linsell, Bairdwear, Celestion and Fermark all collaborated with Loughborough University to interrogate the data produced by the LASS system (Fan et al, 2004). They obtained the data by scanning 155 women of various shapes and sizes (Fan et al, 2004, Hardaker & Fozzard, 1997).	Loughborough University Prof P., R., M., Jones, HUMAG research Group, Department of Human Sciences, University of Loughborough, Loughborough, Leicestershire, LE11 3TU.	Fan, J., Yu, & W., Hunter, L., (2004)

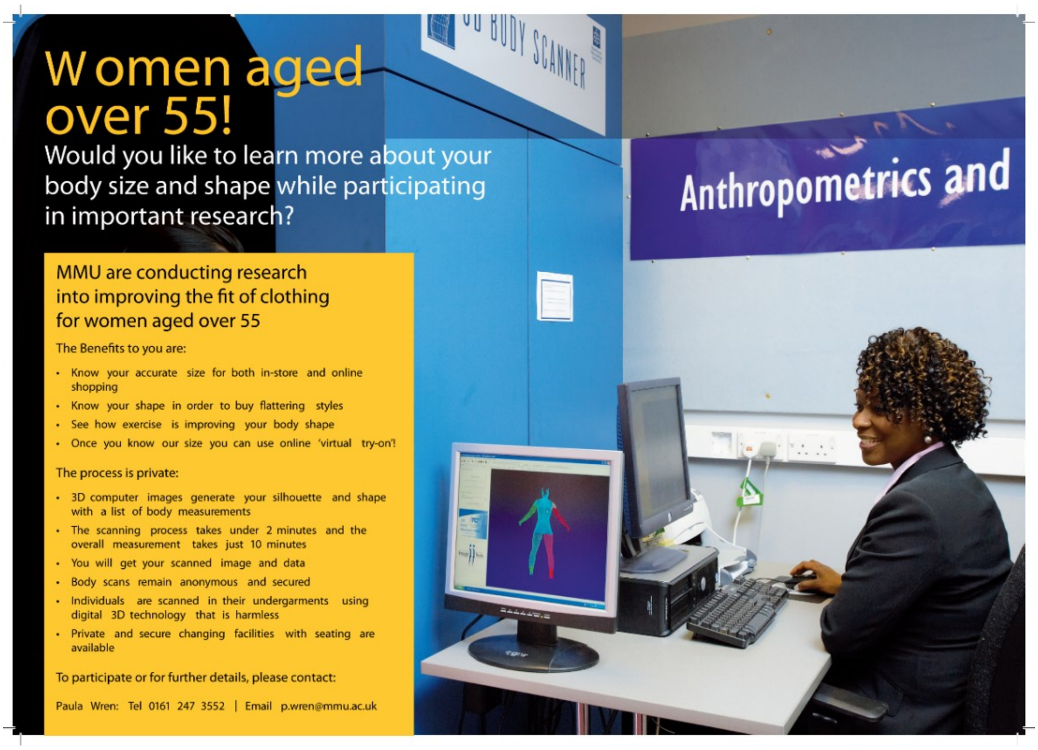
Wicks and Wilson	**Triform** White light Each fringe pattern is captured by a camera and stored in a PC. An additional all white frame is captured and used to produce the colour texture map of the subject. The distortion of the fringes is then analysed and a 3D point cloud of the subject produced (Roger, Flack & McCarthy, 2007). **TriForm BodyShape Scanner**	**TriBody** software Processes the scan data to produce a three dimensional point cloud containing approximately 1.5 million coordinate points. Allows colour viewing. Stitches and merges the different view to give 3 D viewing. Has editing (smoothing, noise reduction etc) tools and generates measurements **Automatic measurement extraction, no database interface (Kirchdörfer, & Rupp, 2006)**	Due to the time it takes to scan subjects may move so accuracy maybe reduced regarding measurement extraction.	Patterned light is projected onto the subject from a projector (not specified how many projectors are present. Has 4 cameras that give 8 views (2 views each?) the cameras follow diagonal trajectories across the body.	Fringe projection similar to the TC2 scanner (Roger, Flack & McCarthy, 2007). Fitting booth style. Scans in 10 seconds and point cloud data is available to view in 1 minute	NTU Nottingham Trent University survey (Kirchdörfer, & Rupp, 2006)	Wicks and Wilson Limited Phone: +44 (0) 1256 842211 Email: sales@wwl.co.uk	(Kirchdörfer, & Rupp, 2006), (Roger, Flack & McCarthy, 2007)

25

17 Appendix I

17.1 Posters to recruit women aged 55+ for both Manchester and Nottingham bodyscanning

17.1.1 Manchester



17.1.2 Nottingham

18 Appendix J

18.1 3D Body scanning participant questionnaire

Garment Preference and Fit Survey for Mature Women (55+)

Paula Wren, Department of Clothing Design & Technology
Room 306, Hollings Faculty, Old Hall Lane, Fallowfield
Manchester, M14 6HR
Tel: 0161 247 3552 or 07972 106727
Email: P.Wren@mmu.ac.uk

SUBJECT CODE

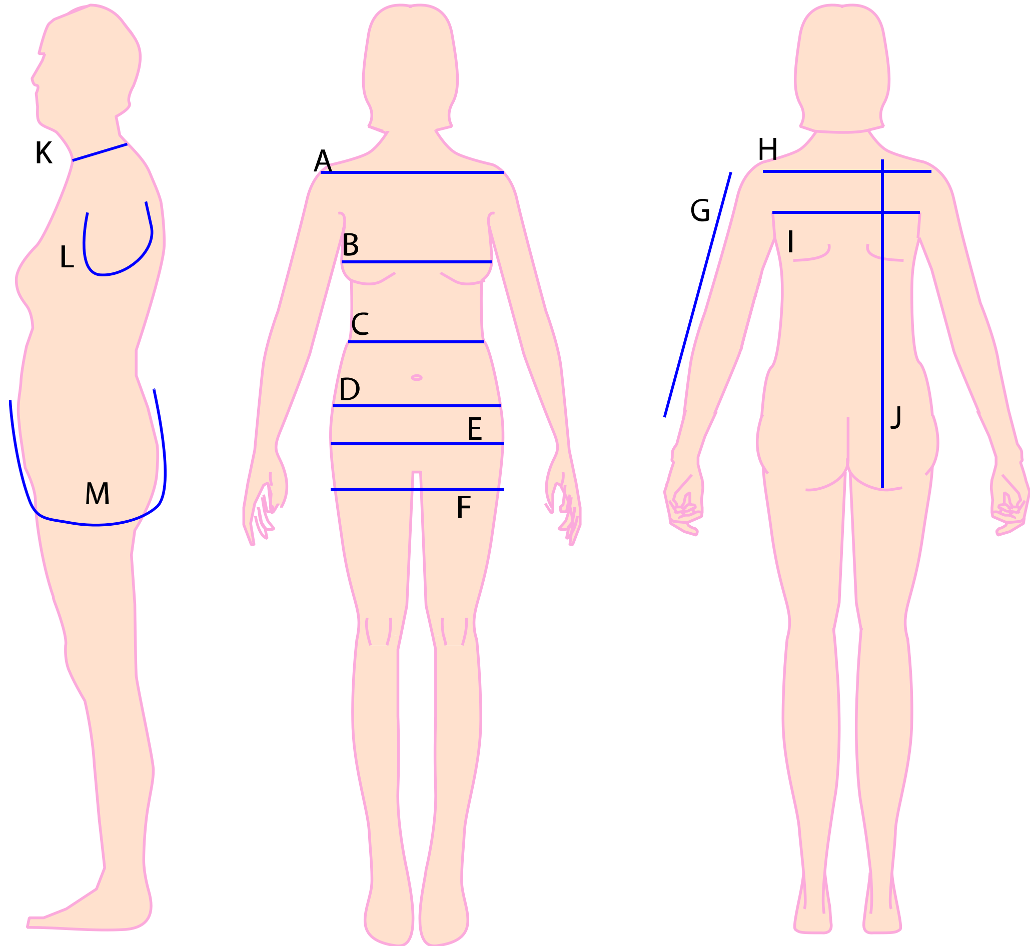
Your details

Participants Name				
I am size.....	Dress	Skirt	Trousers	Top

	Trousers	**Skirts**	**Dresses**	**Casual tops**	**Blouse**
1. What type of garments do you usually wear day to day? (Please X one or more)					
I find this garment comfortable because....					

	Trousers	**Skirts**	**Dresses**	**Casual tops**	**Blouse**
2. Do you have problems with any particular garments fit? If yes please X the applicable garment.					

3. Look at these images and then read the statement in the grey box. If yes mark an X



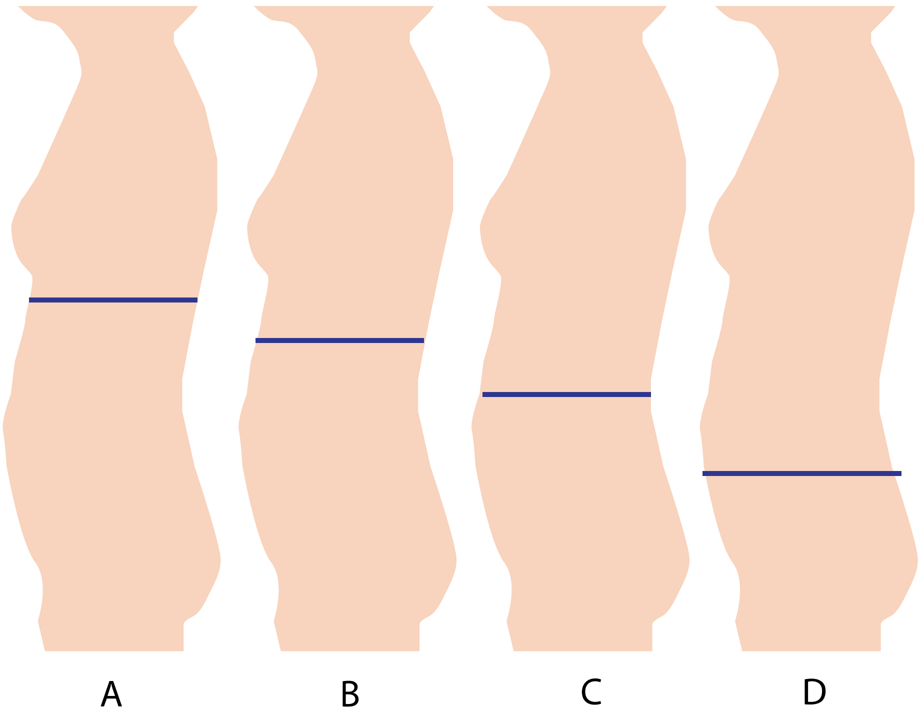
Garments do not fit me properly in the following area/s					
A front shoulders	B bust	C waist	D hip	E bottom	F thighs
G arms	H back shoulders	I across the back	J torso length	K neck	L underarm
M crotch					

4. In what way does the garment not fit you properly? Please use this box for your reply.

5. Is this poor fit recurring problem?	Yes	No

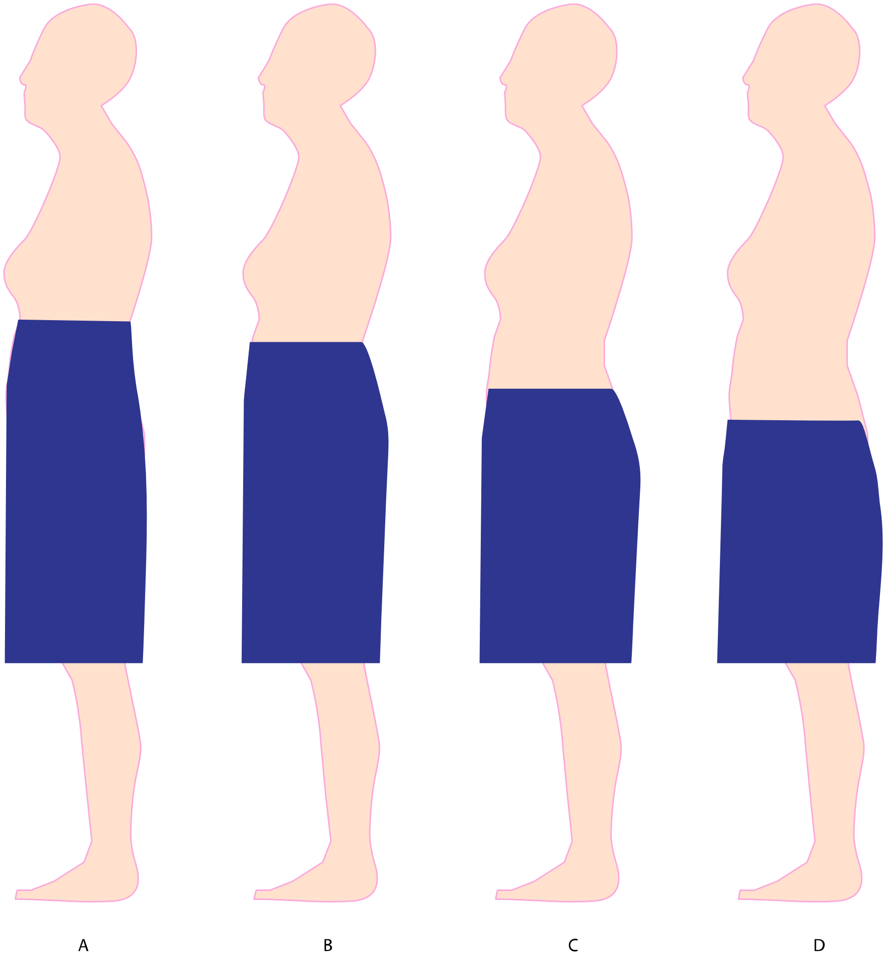
Where do you normally buy your clothes?
6. I normally shop at….(please use this box for your reply)

7. If you are wearing a waistband or garment with a waist seam please indicate its position on your body by X the one of the images below in the boxes available. If none of the images are suitable please leave blank.



A		B		C		D	

8 Please look at these images. Now please make X next to the letter below where you feel it is comfortable to wear your waistband.



A		B		C		D	

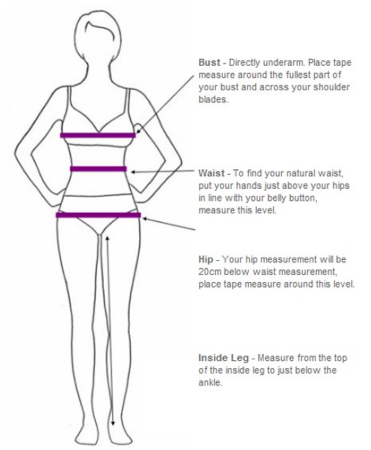
Thank you for completing this survey!

19 Appendix K

19.1.1 Retailers measurement guidance

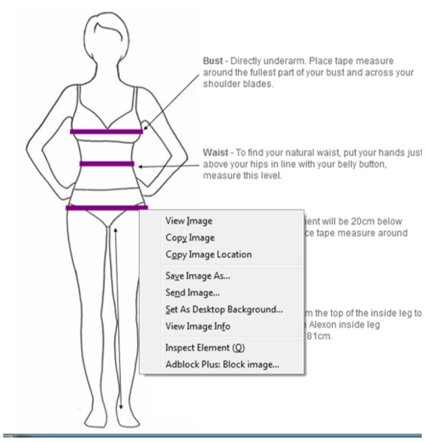
Company	Measurement Guidance and size charts

Alice Collins



Alexon, Eastex

***The measurements may vary slightly on individual garments due to the specific styling.



Artigiano Ltd

SIZE GUIDE

To help you choose the size to best suit you, please refer to the size charts and guidelines below.

Garments may vary slightly in size specifications depending on the design; when choosing knitwear in particular please consider the look and fit you desire.

If you should need any further advice please phone us on 0844 4822345 or email customercare@artigiano.co.uk.

Bust - measure around the fullest part of the bust.

Waist - measure around natural waistline keeping the tape measure comfortably loose.

Hips - measure around the fullest part of the hips.

Skirt Lengths - measured from under the waistband to the hem line.

Jacket Lengths - measured from the centre back of the neck to the hem.

Knitwear Lengths - measured from the neck point at shoulder to hem.

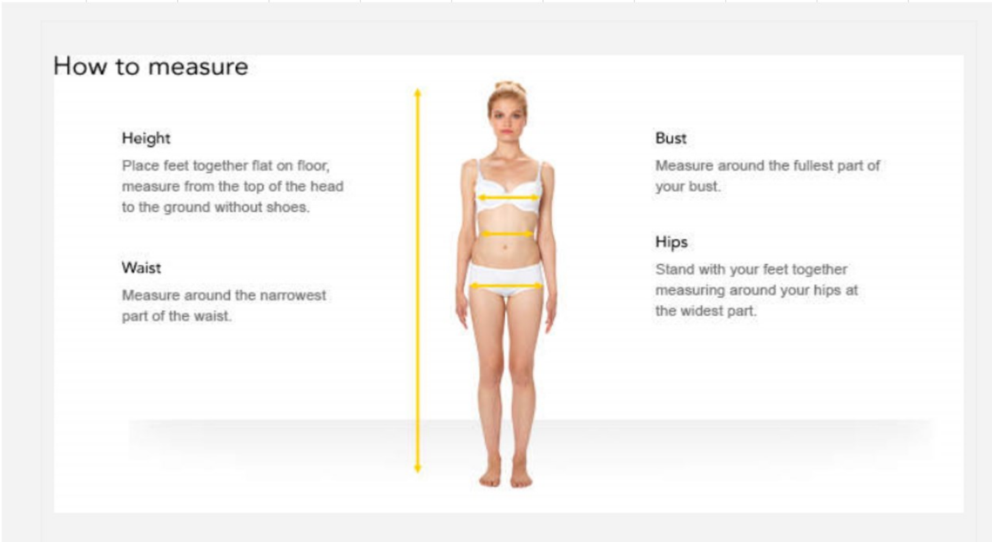
Inside Leg Lengths - measured from the crotch, down the inside leg seam, to the hem.

Unfinished Trouser Hems - the inside leg length measures 86cm (34").

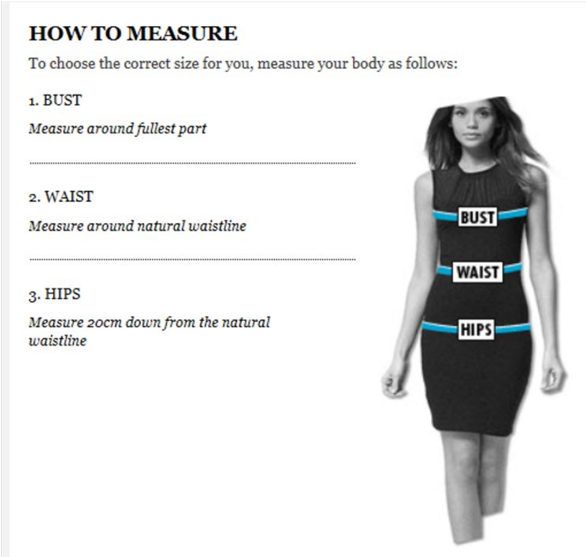
The approximate lengths or dimensions of an item are given within the descriptive text relating to the item.

ARTIGIANO, SIZES 8-20

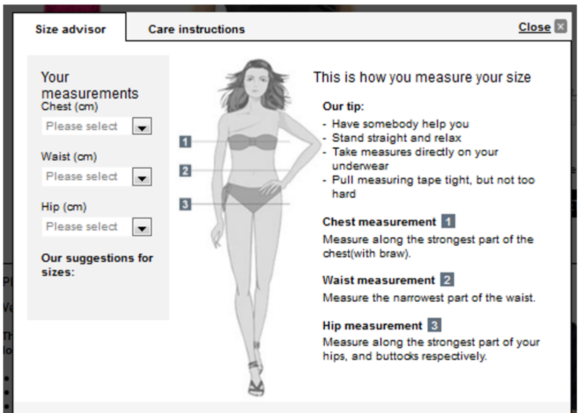
ASDA - George



ASOS



Betty Barclay/Vera Mont



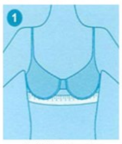
	XS	S		M		L		XL	
	6	8	10	12	14	16	18	20	22
Chest (cm)	79-81	82-84	85-88	89-92	93-96	97-100	101-105	106-110	111-116
Waist (cm)	61-63	64-66	67-70	71-74	75-78	79-82	83-87	88-92	93-98
Hip (cm)	87-89	90-92	93-96	97-100	101-104	105-108	109-113	114-118	119-124

7

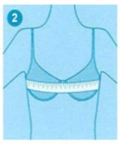
8 Bhs

Lingerie and Sleepwear Size Guide

First you need to take the following 2 measurements:



Underband/bra size



Cup size

Then look up those measurements in the table below to find your correct bra size

1 Underband/ bra size		2 Cup size							
cm		AA	A	B	C	D	DD	E	F
63-67	30	75-77	77-79	79-81	81-83	83-85			
68-72	32	80-82	82-84	84-86	86-88	88-90	90-92	92-94	94-96
73-77	34	85-87	87-89	89-91	91-93	93-95	95-97	97-99	99-101
78-82	36	90-92	92-94	94-96	96-98	98-100	100-102	102-104	104-106
83-87	38	95-97	97-99	99-101	101-103	103-105	105-107	107-109	109-111
88-92	40	100-102	102-104	104-106	106-108	108-110	110-112	112-114	114-116

Boden

ize & outfits ♦ Size charts ♦ **Women's fit & size charts**

WOMEN'S SIZE CHARTS

To help you choose the best size, please use the size guidelines below. If you have any questions about the sizes of clothes, please call our Customer Service Department on 0844 873 0000.

HOW TO MEASURE GUIDELINES

Taming your tape measure: We want your clothes to feel comfortable, so no need to pull your tape measure too tight. It's often easier for someone else to get the tape measure in the right place, so try measuring with a friend.

Bust: Place the tape measure under your arms, over your shoulder blades and across the fullest part of your bust. Remember to breathe out first.

Waist: Measure around your natural waist. You can find it by bending to the side like a teapot (singing is optional).

Hips: Measure around the fullest part of your bottom at the top of the leg, at about 20cm/8 inches below your natural waist.

Waist position guide: When working out which size to order, always measure your natural waist. All our skirts are designed to fit the natural waist unless otherwise stated. Trousers will be described in one of the following two ways:

- Natural waist,
- Below natural waist – which means about 4.5cm (1½ inches) below your natural

BonMarche

Bonmarche Size Guide

Single sized body measurements

Taken on the circumference in centimetres and inches

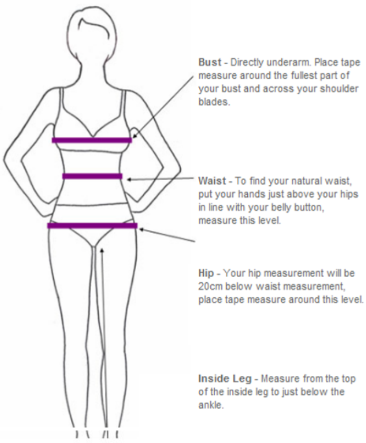
	size 10	size 12	size 14	size 16	size 18	size 20	size 22	size 24	size 26
BUST measured over the fullest position	87cm 34"	92cm 36"	97cm 38"	102cm 40"	107cm 42"	112cm 44"	117cm 46"	122cm 48"	127cm 50"
WAIST	69cm 27"	74cm 29"	79cm 31"	84cm 33"	89cm 35"	94cm 37"	99cm 39"	104cm 41"	109cm 43"
HIP measured at 20cm (8") below wasitline	94cm 37"	99cm 39"	104cm 41"	109cm 43"	114cm 45"	119cm 47"	124cm 49"	129cm 51"	134cm 53"

Dual sized body measurements

Taken on the circumference in centimetres and inches

	size S To fit sizes (12-14)	size M To fit sizes (16-18)	size L to fit sizes (20-22)	size XL to fit size 24
BUST measured over the fullest position	92-97cm 36-38"	102-107cm 40-42"	112-117cm 44-46"	122cm 48"
WAIST	74-79cm 29-31"	84-89cm 33-35"	94-99cm 37-39"	104cm 41"
HIP measured at 20cm (8") below wasitline	99-104cm 39-41"	109-114cm 43-45"	119-124cm 47-49"	129cm 51"

10

11	Bruswick Group (for Eastex)	
12	Chesca	see Chesca sizing guide below
	Coast	see below

Chesca sizing guide

UK Sizing	Chesca Sizing	Bust		Waist		Hips	
		in	cm	in	cm	in	cm
12	1	39.5	100	32	82	43	110
14	1	42	106	34.5	88	45.5	116
16	2	44	112	37	94	48	122
18	2	46.5	118	39.5	100	50.5	128
20	3	49	126	42	106	53	134
22	3	51	130	44	112	55	140
24	4	53.5	136	46.5	118	57.5	146

Coast

HOW TO MEASURE

BUST

Measure around the fullest part of your bust and across your shoulder blades

WAIST

Keeping the tape measure taut, measure around your natural waist – generally an inch above your belly button

HIPS

Stand with your feet together. Put the tape around the fullest part of your bottom at the top of your leg

LENGTH - ABOVE THE KNEE

48cm | Measured from the waist as you would for a skirt length

LENGTH - ON THE KNEE

52cm | Measured from the waist as you would for a skirt length

LENGTH - MAXI

109cm | Measured from the waist as you would for a skirt length

LENGTH - BRIDAL MAXI

115cm | Dress lengths are measured from the waist as

Country Casuals

how to measure

Bust

Measure round the fullest part of your bust

Waist

Measure round your natural waist

Hips

Measure round the widest part of your hips (approx. 20cm from waist)

Main range sizes range from 8 to 20

Main range is based on a persons height of 170cm / 5' 7"

14

Damsel in a dress

Measurement Point	8	10	12	14	16	18
BUST (CMS)	88	92	96	101	106	111
WAIST (CMS)	69	73	77	82	87	92
HIPS (CMS)	95	99	103	108	113	118
BUST (INCHES)	34	36	38	40	42	44
WAIST (INCHES)	27	29	31	33	35	37
HIPS (INCHES)	37	39	41	43	45	47
		S	M	L		
BUST (CMS)		88-92	96-101	106-111		
WAIST (CMS)		69-73	77-82	87-92		
HIPS (CMS)		95-99	103-108	113 -118		
BUST (INCHES)		34-36	38-40	42-44		
WAIST (INCHES)		27-29	31-33	35-37		
HIPS (INCHES)		37-39	41-43	45-47		

15

David Nieper

Height	4'9" - 5'1"	5'0" - 5'4"	5'2" - 5'8"	5'5" - 5'8"	5'6" - 5'10"

Bra Sizing

Make sure your bra is a perfect fit. Please wear a bra when taking measurements.

- To find your bra size - **1** measure in inches directly under the bust. the tape should be tight around our body and level across your back. If the number is even add 4", if odd add 5". this is your bra size.
- To find your cup size - **2** gently measure around the fullest part of the bust making sure the tape is level across your back. The difference between your bra and your full bust measurement is your cup size.

Same as bra size = A cup

1" more = B cup	2" more = C cup	3" more = D cup	4" more = DD cup
5" more = E cup	6" more = F cup	7" more = FF cup	8" more = G cup

Hence a 36" C cup would be calculated as follows:

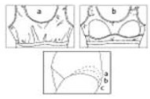
Under bust (1) is 31" plus 5" equals 36 Bra size.

Over bust measurement (2) is 38 (ie. a 2" difference) equals C cup.

Thus your correct bra size is 36C.

Swimwear Sizing

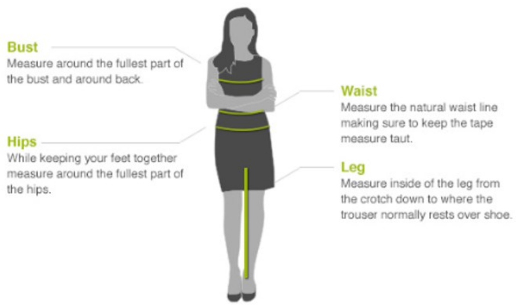
1. Body Length — Regular - will fit almost everyone
   Long - if you are tall or have a long body, you may prefer a long length suit for maximum comfort.
2. Swimsuit Bra Styles — a. Shelf Bra - gentle support built into the lining.
   b. Soft cup Bra - soft preformed cup giving excellent support and shape enhancement
3. Leg Length — a. High Cut - lengthens the look of the leg by exposing more hip.
   b. Medium Cut - possibly the most flattering, and stretchy fabric allows you to adjust the cut a little higher or lower as you prefer.
   c. Low Cut - Perfect for maximum coverage.



Retailer	Size guide
Dunnes	see below

Dunnes

Measurement guides



Clothing

Ireland/UK	8	10	12	14	16	18	20	22
Bust (in)	32	34	36	38	40½	43	45½	48
Bust (cm)	82	87	92	97	103	109	115	121
Waist (in)	26	28	30	32	34½	37	39	41½

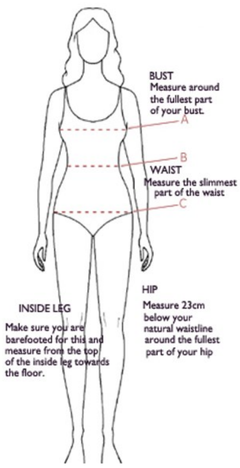
East Ltd

SIZE GUIDE

This means that you may find our sizes more generous than other high street retailers so it may be worth trying a smaller size.

Our size guide lists the measurements we use when designing each garment. However, just like individuals styles and fit can vary so please refer to the product page for any specific recommendations that we have.

If you need help or advice please contact us on +44 (0) 208 877 6543



	SIZE	8	10	12	14	16	18
BUST	CM	84	89	94	100	106	112
	INCHES	33	35	37	39	41	43
WAIST	CM	67.5	72.5	77.5	83.5	89.5	95.5
	INCHES	27	28	30	32	35	37
HIP	CM	90	95	100	106	112	118
	INCHES	35	37	39	41	44	46

DUAL SIZES	XS	S	M	L	XL	XXL
	8-10	10-12	12-14	14-16	16-18	18-20

International Sizes

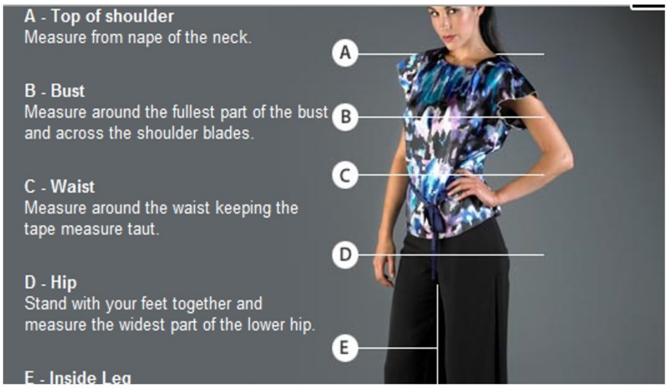
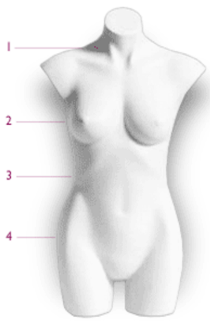
U.K	8	10	12	14	16	18
U.S	6	8	10	12	14	16
FRANCE	36	38	40	42	44	46
GERMANY	34	36	38	40	42	44

Edinburgh Woollen Mill

SIZE GUIDE

WOMENS MEASUREMENT GUIDE	
Point of measure:	NB: all measurements are body measurement not garment measurement.
Bust	Bust to be measured around the fullest part of the bust.
Waist	Waist to be measured around the natural waistline.
Hip	Hip to be measured around the hip, 20cm or 8" below the natural waistline.
Leg	Leg length to be measured from the crotch down to where your trouser is normally worn.

19

20	Eleganze Ltd	
21	Elvi	Size Guide Return to Previous Page We believe that we are experts in sizing and fit, and hope that our guide helps you understand how to measure and size our clothes for you. We have a regular and petite range, and some of our garments are available in dual sizes, which are all explained in detail below. Please do contact our customer services team on 01204 395764 or enquiries@elvi.co.uk if you have any further queries regarding size. Measurement Guide **1. Garment lengths (for tops, jackets and dresses)** Take the length measurement from the collarbone. **2. Bust** Take the measurement across the fullest part. **3. Waist** Measure around the natural wasitline. **4. Hips** measure at the widest part. **5. Inside leg** Measure from the top fo the inside leg at the crotch to the ankle bone. Finished garment sizes will vary depending on whether the style is designed to be worn close fitting or loose fitting according to fashion. 
22	Evans	**How To Measure** To find your correct dress size, measure your bust, waist and top and bottom hips. **Bust** Measure around the fullest part of your bust. **Waist** Measure around your natural waistline, keeping tape comfortably loose. **Top hip** Measure around your hips 4" above the widest part. **Bottom hip** Measure around the widest part of your hips. *Please bear in mind that although garment lengths are listed where applicable, our clothes are cut for an average height of 5ft 6".

<table>
<tr><td>23 Fat Face</td><td>

▼ How to Measure

Chest or Bust: Measure around the fullest part and across the shoulder blades.

Waist: Measure around the natural waistline.

Skirt and dress length: Skirts, measure from just below waistband or natural waistline. Dresses, measure from side neck point. All lengths are given on the product pages.

Inside leg: This is the measurement from crotch seam to the bottom of hem. All lengths are given on the product pages.

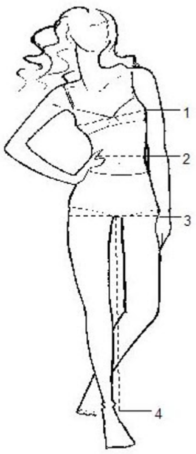
</td></tr>
<tr><td>Fenn Wright & Manson</td><td>

SIZE CHART | HOW TO MEASURE

To ensure that you choose the correct size garment, please follow our guide when ordering from us. With a tape measure, please take the measurements below following the illustration opposite and compare them to the size charts to find your perfect fit/the right size for you.

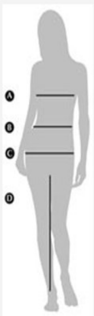
How to measure:

1. **Bust** - Wearing a bra, measure around the fullest part of your bust.
2. **Waist** - Measure around the natural waistline, which is the narrowest part of the waist.
3. **Hip** - Stand with your feet together, measure around fullest part of bottom usually 20cm below the natural waist (18cm for Petites).
4. **Inside Leg** - Measure from the top of the inside leg at the crotch down the leg to the floor.



</td></tr>
<tr><td>25 Frank Usher & Cotorie</td><td>No size chart or measurement guidance available online</td></tr>
<tr><td>Grey and Osbourne (N Brown Group)</td><td>

Sizing Help - Womenswear



When buying fashion via mail order it's important to choose the right size, so we recommend double checking your measurements and referring to the size charts below. Size and fit can vary from brand-to-brand and depending on the cut, fabric and styling of the garment. The size charts below are as a guide only but should help you to order the correct size. Unfortunately not all brands have a size chart.

<table>
<tr><td>A. Bust</td><td>Take measurement across fullest part of the bust and across shoulder blades.</td></tr>
<tr><td>B. Waist</td><td>Measure around the natural waistline.</td></tr>
<tr><td>C. Hips</td><td>Measure hips at fullest part. It is easier if you stand with your feet together, to get a more accurate measurement.</td></tr>
<tr><td>D. Inside Leg</td><td>Measure from the top of the inside leg to where the trousers are normally worn on the shoes.</td></tr>
</table>

</td></tr>
</table>

27

Hobbs

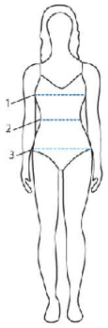
1. HOW TO MEASURE YOURSELF?

MEASURING YOURSELF

To help you choose the best size to flatter your body shape, measure your body without clothes.

1. Bust
Measure around the fullest part of your bust, ensuring the tape meausre isstraight across your back

2. Waist
Take from the slimmest part of your natural waistline



3. Full Hip
With your feet together, measure around the fullest part of your bottom at the top of your legs. This will be approximately It is approximately eight inches / twenty cm below your natural waistline

4. Inside leg:
The distance from the top of the inside leg (at the crotch) to your ankle.

House of Fraser & Rackhams

SIZING GUIDES FROM HOUSE OF FRASER

WOMEN | LINGERIE | MEN | CHILDREN | RINGS | BED LINEN | FURNITURE | SHOES

WOMEN

SIZE GUIDE

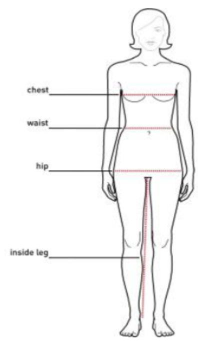
House of Fraser offers a wide range of brands which often vary in size and fit. To help you with your selection, we have created a Size Guide with Fit recommendations for each brand.

Size Guide	This gives you approximate body measurements used by each brand
Fit	Fit descriptions are; **Fitted** - Fits close to the body and could be a tight fit. **Standard** - Is neither fitted or loose. **Comfort** - A relaxed roomier fit
Length	Available lengths to fit different heights. Short - 5ft3" and below Regular 5ft4"-5ft7" Long 5ft8" and above

HOW TO MEASURE

Measuring your body is more accurate than measuring over your clothes

Chest	Measure around the fullest part of your chest and across your shoulder blades
Waist	Measure around your natural waist. Keep the tape measure taut
Hips	With your feet together, measure around the fullest part of your bottom (approximately 20cm below waist)
Inside Leg	Measure from the inside leg at the crotch to where the trouser hem is to sit on the shoe, alternatively you can measure a trouser that fits you well



ISME

Size guide | Measuring guide

Clothing | Dress Length | Lingerie | Footwear — Select a category to get further help and information.

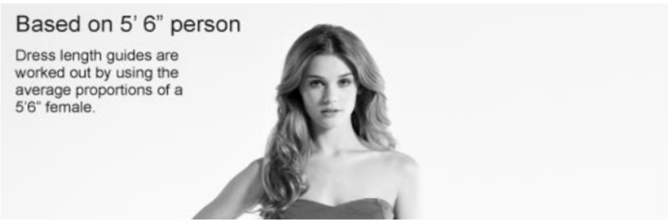
Clothing

The diagram below shows the key points to measure when calculating size, then simply select the correct size from the chart above. It's best to actually take body measurements rather than measuring over clothes. You shouldn't need to 'size up' or 'down' unless you have a particular fit preference of course.

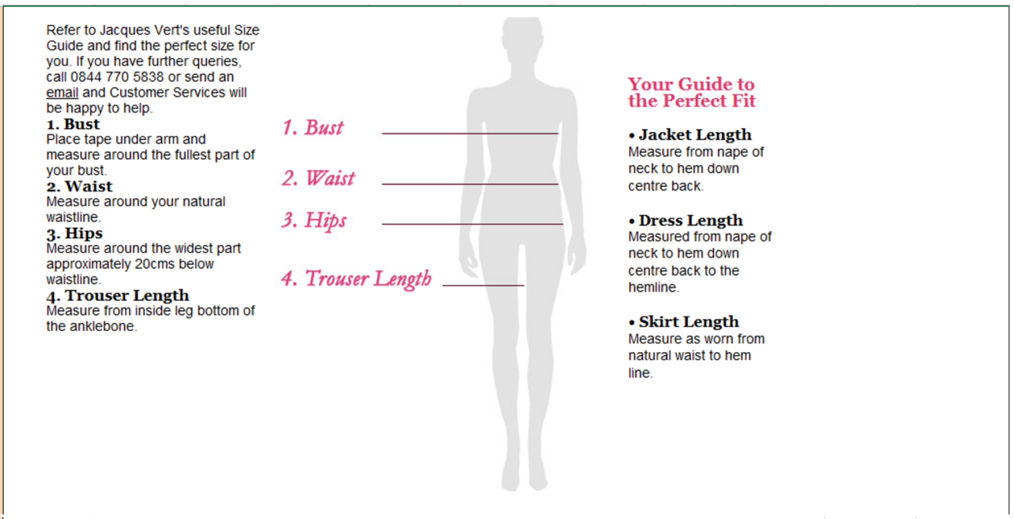
Women's measuring guide

Back to top

Dress Length



30 Jacques Vert


Refer to Jacques Vert's useful Size Guide and find the perfect size for you. If you have further queries, call 0844 770 5838 or send an email and Customer Services will be happy to help.

1. Bust
Place tape under arm and measure around the fullest part of your bust.

2. Waist
Measure around your natural waistline.

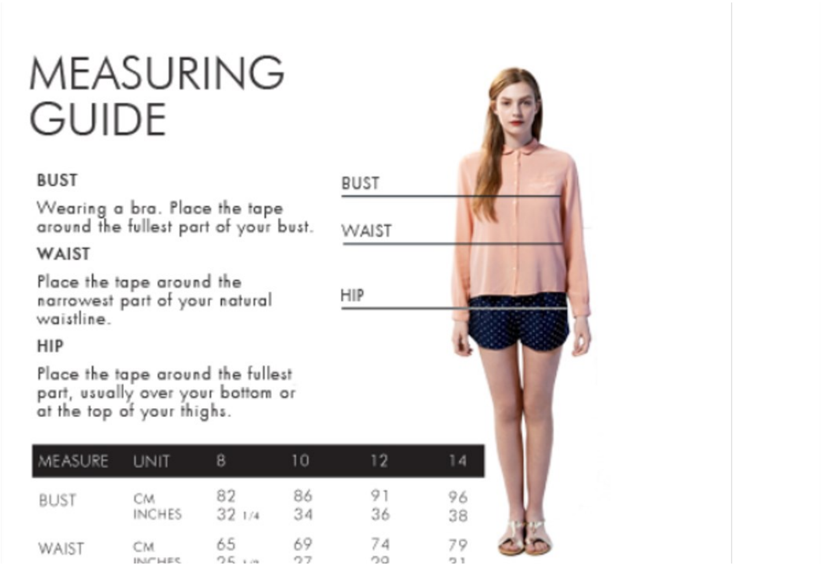
3. Hips
Measure around the widest part approximately 20cms below waistline.

4. Trouser Length
Measure from inside leg bottom of the anklebone.

Your Guide to the Perfect Fit

- **Jacket Length** Measure from nape of neck to hem down centre back.
- **Dress Length** Measured from nape of neck to hem down centre back to the hemline.
- **Skirt Length** Measure as worn from natural waist to hem line.

Jigsaw


MEASURING GUIDE

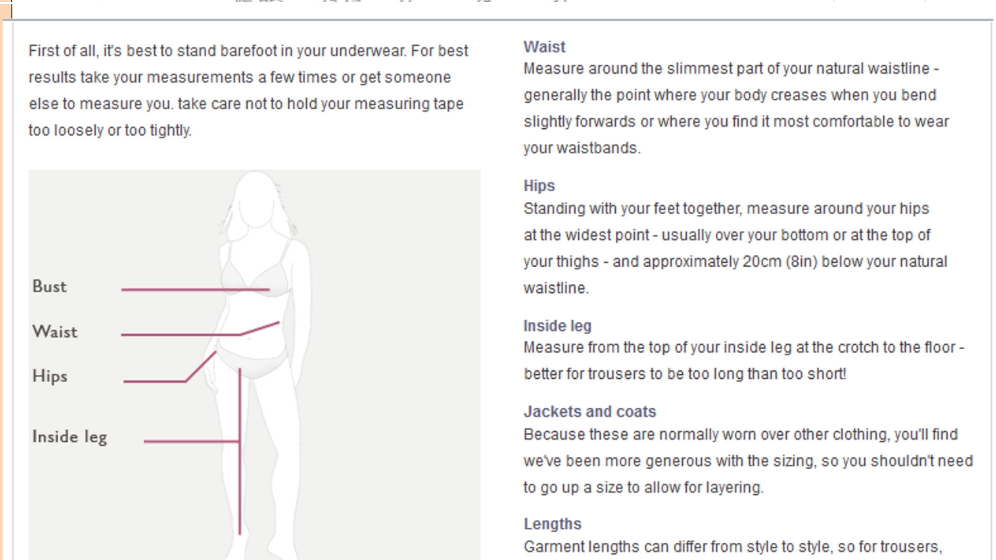
BUST
Wearing a bra. Place the tape around the fullest part of your bust.

WAIST
Place the tape around the narrowest part of your natural waistline.

HIP
Place the tape around the fullest part, usually over your bottom or at the top of your thighs.

MEASURE	UNIT	8	10	12	14
BUST	CM	82	86	91	96
	INCHES	32 1/4	34	36	38
WAIST	CM	65	69	74	79

John Lewis


First of all, it's best to stand barefoot in your underwear. For best results take your measurements a few times or get someone else to measure you. take care not to hold your measuring tape too loosely or too tightly.

Waist
Measure around the slimmest part of your natural waistline - generally the point where your body creases when you bend slightly forwards or where you find it most comfortable to wear your waistbands.

Hips
Standing with your feet together, measure around your hips at the widest point - usually over your bottom or at the top of your thighs - and approximately 20cm (8in) below your natural waistline.

Inside leg
Measure from the top of your inside leg at the crotch to the floor - better for trousers to be too long than too short!

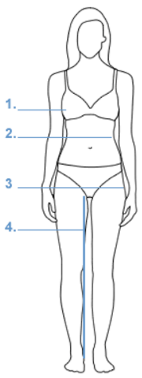
Jackets and coats
Because these are normally worn over other clothing, you'll find we've been more generous with the sizing, so you shouldn't need to go up a size to allow for layering.

Lengths
Garment lengths can differ from style to style, so for trousers,

Brand	Size guide
Jaegar	See below
Kaliko	See below
Karen Millen	See below

Jaegar

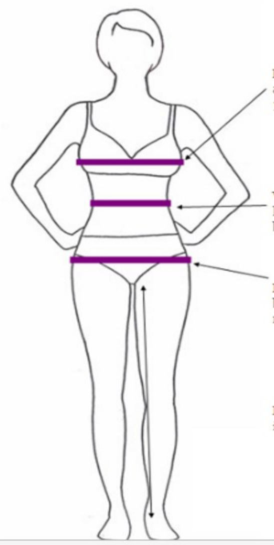
HOW TO MEASURE



1. **Bust** - Measure across the fullest point and across your shoulder blades.
2. **Waist** - Measure around natural waistline.
3. **Hip** - Measure around fullest part of bottom, usually 20cm below the waist.
4. **Inside leg** - Measure from inside leg at the crutch to where the trouser hem is to sit on the shoe.
5. **Gloves** - Measure the circumference of the hand just below the knuckles.

Kaliko

Measuring Guide



Bust - Directly underarm. Place tape measure around the fullest part of your bust and across your shoulder blades.

Waist - To find your natural waist, put your hands just above your hips in line with your belly button, measure this level.

Hip - Your hip measurement will be 20cm below waist measurement, place tape measure around this level.

Inside Leg - Measure from the top of the inside leg to just below the ankle.

Karen Millen

International size guide & measurements

BUST	78.5	81	86	91	96	101
WAIST	60.5	63	68	73	78	83
HIP	86.5	89	94	99	104	109
UK	6	8	10	12	14	16
USA	2	4	6	8	10	12
AUSTRIA, GERMANY, NETHERLANDS, SWEDEN	32	34	36	38	40	42
BELGIUM SPAIN, FRANCE, PORTUGAL	34	36	38	40	42	44
ITALY	38	40	42	44	46	48
RUSSIA	40-42	42-44	44-46	46-48	48-50	50-52

Bust

Measure around the fullest part of your bust.

Waist

Measure around your natural waist.

Hips

Measure around your hips at fullest part (approximately 20cm from natural waist).

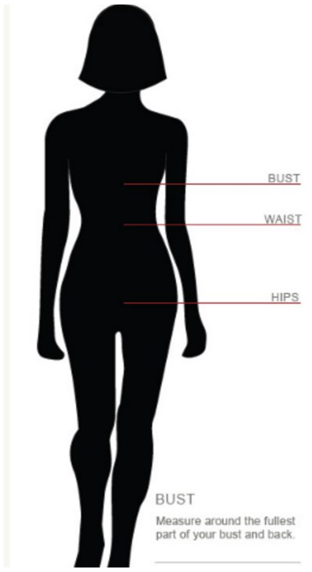
Lengths

The Karen Millen Brand is fitted to a 5.8/1.72m model, therefore the descriptions used on the product information page indicate where the hem line falls on a model of this height.

Knitwear and jersey guide

Belts

L K Bennett



Lands End

Waist

Measure around your waist, in your underwear, at the point where your trousers would normally sit. Keep one finger between the tape and your body.

Hips

Stand with your heels together, and measure around the fullest part of your hips, keeping the tape parallel to the floor.

Inside leg length (inseam)

Take a pair of trousers that fit you well. Measure from crotch seam to the bottom of the leg.

Height

Stand in stocking feet with your feet slightly apart and your back to a wall. Measure from the floor to the top of your head.

Free custom hemming!

Most trousers can be custom finished with plain hems or turn-ups to the nearest ½" (1.5 cm). For styles where turn-ups are not available, no turn-up selection box will appear on the ordering page.

Regular/Plus: plain hem - from 28"/71cm to 34"/86cm
With turn-ups - from 28"/71cm up to 32"/81cm
Unfinished 36"/90cm

UK size		18	20	22	24	26	28	30
Bust/Chest	ins	42 1/2	44	46	48	50	52	54
	cms	108	112	117	123	127	132	137f

Mango

Description of Measurements
Table of equivalent sizes for women
Table of equivalent sizes for men
Sizes guide: lingerie

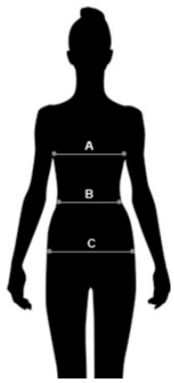
Description of Measurements

Description of Measurements:

A. Bust Size: Measurement taken by placing the tape measure snugly over the fullest part of the bust, around the back and underneath the arms to form as straight a circumference as possible.

B. Waist size: Measurement taken by placing the tape measure snugly around the natural waist to form as straight a circumference as possible.

C. Hip Size: Measurement taken by placing the tape measure snugly around the body and over the fullest part of the buttocks to form as straight a circumference as possible.



M&S

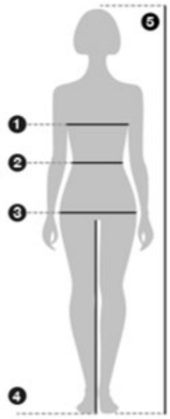
Size guide

1. Bust:
Measure under the arms at the fullest part around the bust horizonatly

2. Waist:
Measure around the natural waistline

3. Hips:
With the feet together measure around fullest part

4. Inside leg:
In bare feet take the measurement from the top of the inside leg and measure down the inside leg to the floor



5. Height:
With bare feet together measure from the top of the head to the floor

Matalan

Ladies Clothing Size Guide

Always measure your actual body, not clothed body to get an accurate reading for sizing. It is advisable to wear a non padded bra to get more accurate bust measurement.

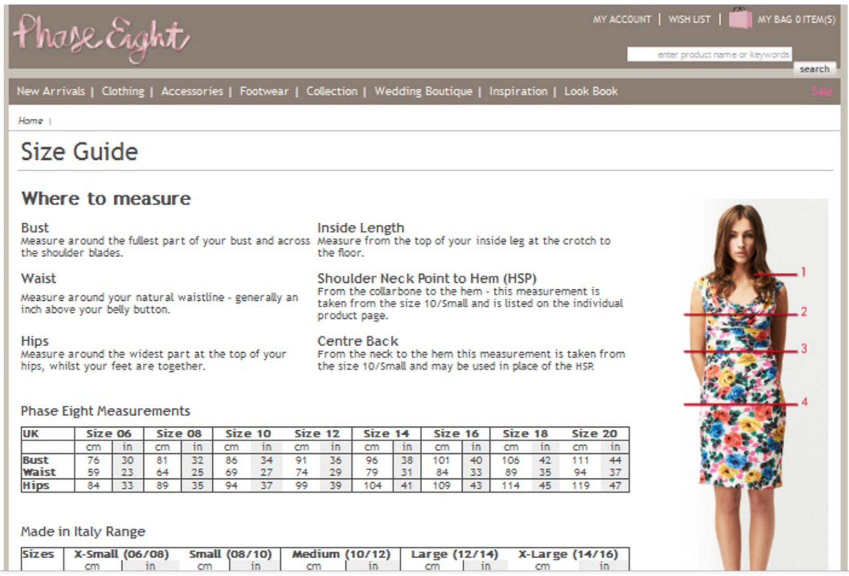
Bust - Measure around the fullest part of your bust and across your shoulder blades.

Waist - Keeping the tape measure taut, measure around your natural waist.

Lower Hip - With your legs together, measure approximately 20cm down from your natural waist and measure around the lower part of your bottom.

Measure Point	Garment Size / Body Measurement											
	Small		Medium		Large		XL		XXL		XXXL	
	8	10	12	14	16	18	20	22	24	26	28	30
Chest / Bust (cm)	82	86	91	96	101	107	113	119	125	131	136	142
Waist (cm)	65	69	73	78	84	91	98	105	111	118	126	133
Lower Hip (cm)	89	93	98	103	108	115	121	128	134	141	147	154

Phase Eight



MY ACCOUNT | WISH LIST | MY BAG 0 ITEM(S)

enter product name or keywords search

New Arrivals | Clothing | Accessories | Footwear | Collection | Wedding Boutique | Inspiration | Look Book Sale

Home |

Size Guide

Where to measure

Bust
Measure around the fullest part of your bust and across the shoulder blades.

Waist
Measure around your natural waistline - generally an inch above your belly button.

Hips
Measure around the widest part at the top of your hips, whilst your feet are together.

Inside Length
Measure from the top of your inside leg at the crotch to the floor.

Shoulder Neck Point to Hem (HSP)
From the collarbone to the hem - this measurement is taken from the size 10/Small and is listed on the individual product page.

Centre Back
From the neck to the hem this measurement is taken from the size 10/Small and may be used in place of the HSP.

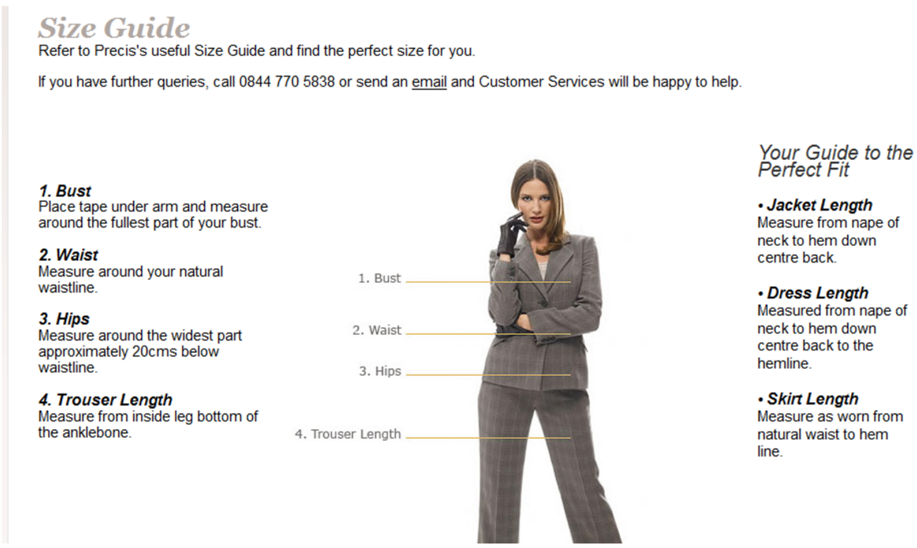
Phase Eight Measurements

UK	Size 06		Size 08		Size 10		Size 12		Size 14		Size 16		Size 18		Size 20	
	cm	in	cm	in	cm	in	cm	in	cm	in	cm	in	cm	in	cm	in
Bust	76	30	81	32	86	34	91	36	96	38	101	40	106	42	111	44
Waist	59	23	64	25	69	27	74	29	79	31	84	33	89	35	94	37
Hips	84	33	89	35	94	37	99	39	104	41	109	43	114	45	119	47

Made in Italy Range

Sizes	X-Small (06/08)		Small (08/10)		Medium (10/12)		Large (12/14)		X-Large (14/16)	
	cm	in	cm	in	cm	in	cm	in	cm	in

Precis



Size Guide

Refer to Precis's useful Size Guide and find the perfect size for you.

If you have further queries, call 0844 770 5838 or send an email and Customer Services will be happy to help.

1. Bust
Place tape under arm and measure around the fullest part of your bust.

2. Waist
Measure around your natural waistline.

3. Hips
Measure around the widest part approximately 20cms below waistline.

4. Trouser Length
Measure from inside leg bottom of the anklebone.

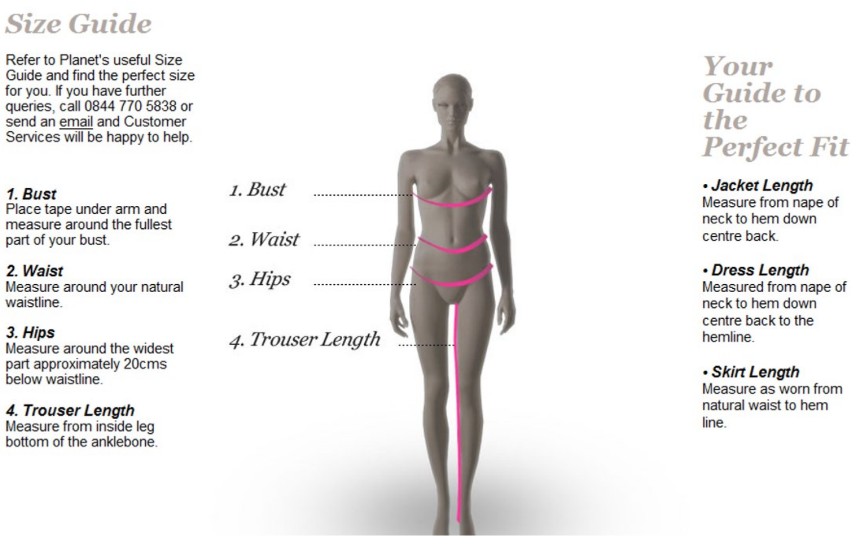
Your Guide to the Perfect Fit

• ***Jacket Length***
Measure from nape of neck to hem down centre back.

• ***Dress Length***
Measured from nape of neck to hem down centre back to the hemline.

• ***Skirt Length***
Measure as worn from natural waist to hem line.

Planet



Size Guide

Refer to Planet's useful Size Guide and find the perfect size for you. If you have further queries, call 0844 770 5838 or send an email and Customer Services will be happy to help.

1. Bust
Place tape under arm and measure around the fullest part of your bust.

2. Waist
Measure around your natural waistline.

3. Hips
Measure around the widest part approximately 20cms below waistline.

4. Trouser Length
Measure from inside leg bottom of the anklebone.

Your Guide to the Perfect Fit

• ***Jacket Length***
Measure from nape of neck to hem down centre back.

• ***Dress Length***
Measured from nape of neck to hem down centre back to the hemline.

• ***Skirt Length***
Measure as worn from natural waist to hem line.

Reiss

BUST

Measure around the fullest part of your bust keeping the tape measure straight and taut

WAIST

Measure the narrowest part of your natural waistline - aim for above your navel and below your ribcage

HIP

Measure yourself at the lowest and fullest part of your hip - to incorporate your bottom

INSIDE LEG

Rohan

No measurement guidance available online

Women's Body Measurements

		8	10	12	14	16	18	20
Bust	(inches")	33	35½	37½	39½	41½	43½	45
	(cm)	85	90	95	100	105	110	115
Waist	(inches ")	27	29	31	33	35	37	39
	(cm)	69	74	79	84	89	94	99
Hip	(inches ")	35	37	39	41	43	45	47
	(cm)	89	94	99	104	109	114	119

Women's XS, S, M, and L

	XS	S	M	L	XL
To fit	8-10	10-12	12-14	16-18	18-20

Women's Leg Length's

	Short	Regular	Long
inches "	29	31	33
cm	74	79	84

Roman Originals

Dual Size Chart:	S		M		L		XL		XXL	
	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES
Bust	86.25 - 93	34" - 36½"	94 - 100.75	37" - 39½"	101.75 - 108.5	40" - 42½"	109.5 - 116.25	43" - 45½"	117.25 - 124	46" - 49"
Waist	66.75 - 75	26½" - 29½"	76 - 84.25	30" - 33";	85.25 - 93.5	33½" - 36½"	94.5 - 102.75	37" - 40½"	103.75 - 112	41" - 44"
Full Hips	91.75 - 100	36" - 39½"	101 - 109.25	40" - 43"	110.25 - 118.5	43½" - 46½"	119.5 - 127.5	47" - 50"	128.75 - 137	50½" - 54"

1 Bust :

Measure around the fullest part over the bust point.

2 Waist :

Measure around the smallest part of the waist.

3 Full Hips :

Measure around the widest section of your hips ensuring tape measure goes around your bottom

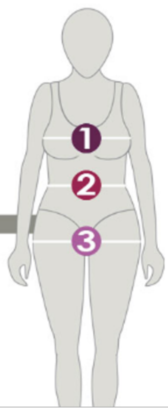
HINTS AND TIPS:

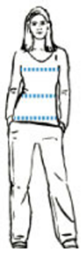
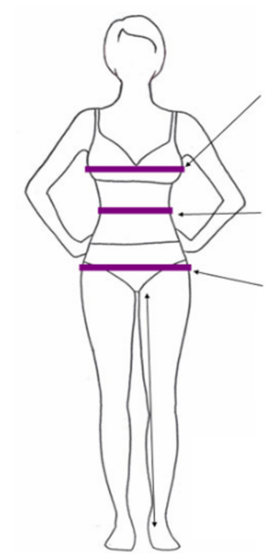
1 Bust :

Measure around the fullest part of the bust and ensure the tape measure covers the bust point and fits around the widest section of your back.

2 Waist :

Tie a piece of string around the smallest part of your body and left it sit into a comfortable position, this will be the NATURAL WAIST.



	Rowland's Clothing	How to measure **Bust/Chest:** Place tape measure around the fullest part of te bust and across your shoulder blades **Waist:** Measure around your natural waist keeping two fingers between the tape and your body **Hips:** Measure around fullest part, keeping the tape measure comfortably loose. **Inside Leg:** Measure from the top of the inside leg seam to the bottom of the hem **Length:** Measure from your natural waistline to hem. All skirt lengths quoted are taken from below the waistband unless otherwise stated.
	Sea Salt	Please note the chart below shows BODY MEASUREMENTS. To check the measurements of a specific garment please see the size guide tab located on each product page. WOMEN'S BODY MEASUREMENTS CONVERT TO INCHES (see table below)  HOW TO MEASURE Bust Measure a full circumference around the fullest part of the chest or bust including the shoulder blades. Be sure to keep the tape measure straight and level. Waist Measure a full circumference just above the natural waistline. Again, ensure tape measure is straight and level. Hips
	Shop Direct (K&Co catalogue)	
49	Shubette of London Ltd (Gina Bacconi)	No size chart or measurement guidance available online
50	Slimma Plc	No size chart or measurement guidance available online

Sea Salt — WOMEN'S BODY MEASUREMENTS:

Size	8	10	12	14	16	18	20
Bust (cm)	81	86	91	96	102	108	114
Waist (cm)	66	71	76	81	87	93	99
Hip (cm)	93	98	103	108	114	120	126

Tesco

WOMEN | MEN | KIDS & BABIES

MEASURING TIPS | SIZE CHART | BRAS | SHOE & SOCK | HOSIERY | FOOTWEAR LABELLING

WOMEN'S SIZE GUIDE

Branded Sizing

The sizing of our branded products may differ from the F&F sizing.

Measuring tips

The fit of your clothes will be dependant on cut, fabric and styling.

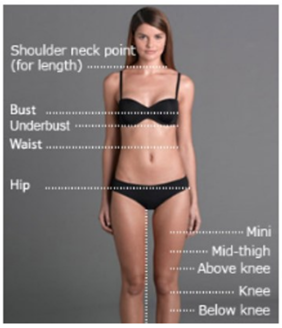
By measuring yourself according to our measuring tips and comparing your body measurements with the size charts, you will be able to select the size closest to your body measurement.

Measuring tips for accurate results:

Take your measurements wearing underwear, do not measure over outer clothes.
Keep both feet flat on the floor.
Get someone else to measure you if possible.
Make sure the tape measure is level around your body and do not pull too tight.

Where to measure:

Bust: take measurement across fullest part of the bust keeping tape level around the back.
Waist: measure around your natural waistline.
Hips: measure at the fullest part of your bottom, keeping the tape measure level.
Inside leg: measure from the top of the your inside leg to the level on your shoe where you want your trousers to finish.



TIGI Wear

Size Guide

The fit of your clothes depends on the cut, fabric and styling of the garment. Garments will vary in size and fit dependent on the amount of ease allowed over the body. This will vary according to the fabric used.

For sizing, you should measure your actual body measurements, as this will be more accurate than measuring over your clothes.

- Bust - measure around the fullest part and across your shoulder blades
- Waist - measure around your natural waist
- Hips - Stand with your feet together. Measure around the fullest part of your bottom at the top of your leg
- Inside leg - measure from the top at the crotch, to where the trousers are normally worn on the shoes

52

Toast

SIZE & FIT

SIZING

The following information is to help you select the correct size. Sizing charts can be a bore but used in conjunction with your own accurate measurements they will really help to obtain a good fit. If you don't have time to measure yourself (life may be too short for that after all), just have a conversation with our operators who have been well trained on our sizing in general and on individual garments in particular.

You will also find some extra notes on the fit of certain garments on the individual product pages of the website.

HOW TO MEASURE YOURSELF REALLY WELL

How you go about this makes an enormous difference to the accuracy of the measurements. This is our preferred method. In true Blue Peter fashion you will need a measuring tape, string, some sellotape and for one measurement, a good friend.

toast measuring guide

WOMEN'S

1. All measurements are best taken when you are wearing underwear only.
2. Bust - Wear only a simple bra and measure around the bust at the fullest part. Make sure the tape is even around the back.
3. Waist - We sometimes refer to three definitions of waist measurement – 'waist', 'below waist' and 'low waist'. To start, tie a length of string or knitting wool around your waist (this is much higher than you expect, it is the narrowest part). Then, measure with a tape around the position of the string. This is how we define the term 'waist'. 'Below waist' and 'low waist' are approximately 2.5cm and 5cm lower respectively. Leave the string on in order to take your next measurement.
4. Hip - At the side of your hip, measure 20cm down from the string around your waist. Use the sellotape to mark this spot. Now measure around the hips at this point remembering to keep the tape level.
5. Leg Length - Ask your (good) friend to measure from your crotch to

Wallis

CLOSE X

HOW TO MEASURE

HOW TO MEASURE | SIZE CONVERSIONS | PETITE SIZE GUIDE | BEACHWEAR SIZE GUIDE | SHOE SIZE GUIDE

Follow our simple measuring guide to find the best size for you. Measure as decribed below, then enter your measurements into our calculator and we'll tell you your size!

BUST
Measure your body around the fullest part of your bust

WAIST
Measure your body around your natural waistline

LEG LENGTH
Measure from the crotch to the ankle bone.

HIPS
Measure your body around the fullest part of your hips

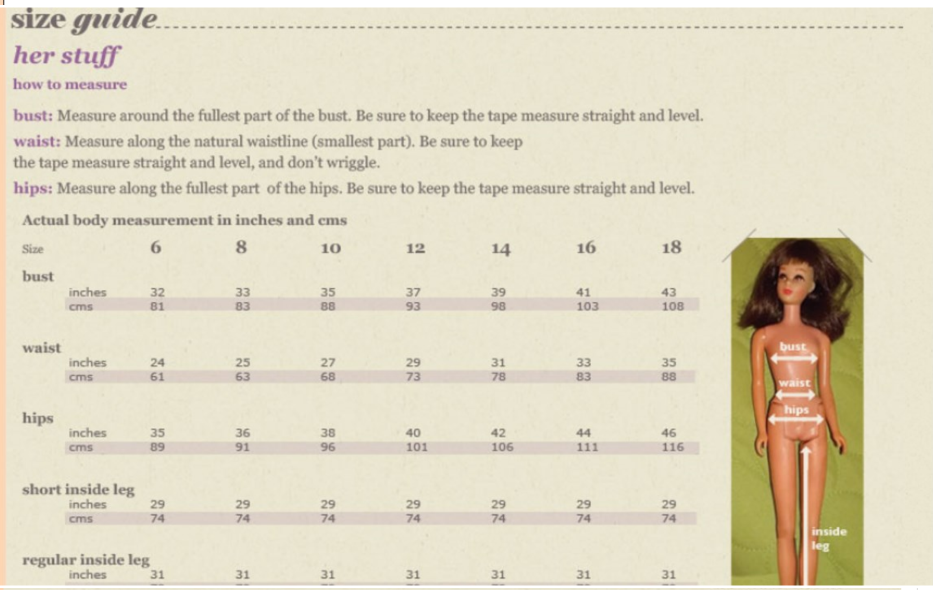
SIZE CALCULATOR

Enter your measurements below to find your perfect Wallis size. All sizes on this site are UK sizes.

Cms/inches:	cms
Bust:	80
Natural waist:	64
Hips:	87

FIND SIZE

Whitestuff



size guide

her stuff

how to measure

bust: Measure around the fullest part of the bust. Be sure to keep the tape measure straight and level.

waist: Measure along the natural waistline (smallest part). Be sure to keep the tape measure straight and level, and don't wriggle.

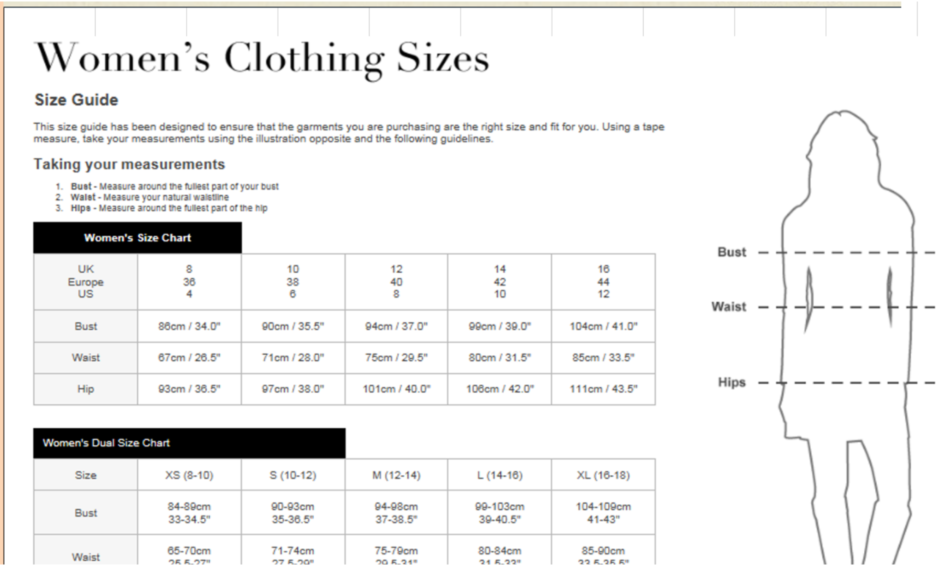
hips: Measure along the fullest part of the hips. Be sure to keep the tape measure straight and level.

Actual body measurement in inches and cms

Size		6	8	10	12	14	16	18
bust	inches	32	33	35	37	39	41	43
	cms	81	83	88	93	98	103	108
waist	inches	24	25	27	29	31	33	35
	cms	61	63	68	73	78	83	88
hips	inches	35	36	38	40	42	44	46
	cms	89	91	96	101	106	111	116
short inside leg	inches	29	29	29	29	29	29	29
	cms	74	74	74	74	74	74	74
regular inside leg	inches	31	31	31	31	31	31	31

bust
waist
hips
inside leg

The White Company



Women's Clothing Sizes

Size Guide

This size guide has been designed to ensure that the garments you are purchasing are the right size and fit for you. Using a tape measure, take your measurements using the illustration opposite and the following guidelines.

Taking your measurements

1. **Bust** - Measure around the fullest part of your bust
2. **Waist** - Measure your natural waistline
3. **Hips** - Measure around the fullest part of the hip

Women's Size Chart

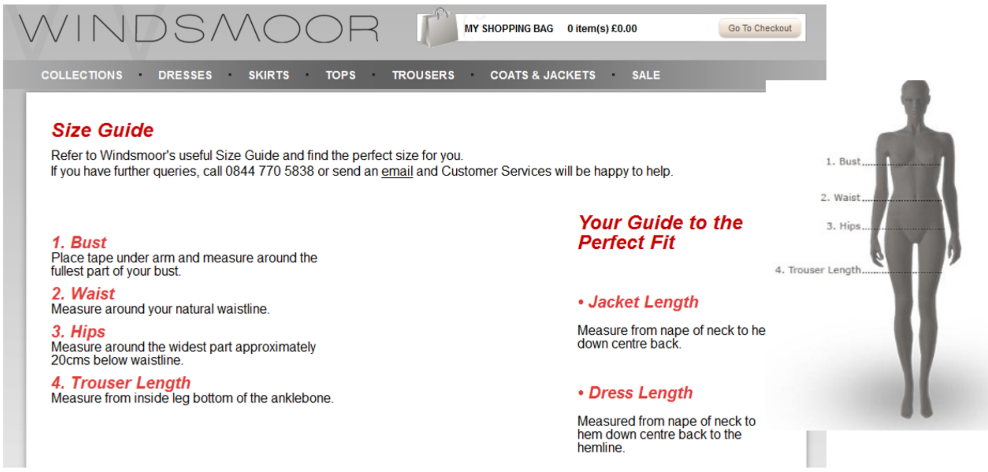
UK / Europe / US	8 / 36 / 4	10 / 38 / 6	12 / 40 / 8	14 / 42 / 10	16 / 44 / 12
Bust	86cm / 34.0"	90cm / 35.5"	94cm / 37.0"	99cm / 39.0"	104cm / 41.0"
Waist	67cm / 26.5"	71cm / 28.0"	75cm / 29.5"	80cm / 31.5"	85cm / 33.5"
Hip	93cm / 36.5"	97cm / 38.0"	101cm / 40.0"	106cm / 42.0"	111cm / 43.5"

Women's Dual Size Chart

Size	XS (8-10)	S (10-12)	M (12-14)	L (14-16)	XL (16-18)
Bust	84-89cm 33-34.5"	90-93cm 35-36.5"	94-98cm 37-38.5"	99-103cm 39-40.5"	104-109cm 41-43"
Waist	65-70cm	71-74cm	75-79cm	80-84cm	85-90cm

Bust
Waist
Hips

57 Windsmoor


WINDSMOOR

MY SHOPPING BAG 0 item(s) £0.00 Go To Checkout

COLLECTIONS • DRESSES • SKIRTS • TOPS • TROUSERS • COATS & JACKETS • SALE

Size Guide

Refer to Windsmoor's useful Size Guide and find the perfect size for you.
If you have further queries, call 0844 770 5838 or send an email and Customer Services will be happy to help.

1. Bust
Place tape under arm and measure around the fullest part of your bust.

2. Waist
Measure around your natural waistline.

3. Hips
Measure around the widest part approximately 20cms below waistline.

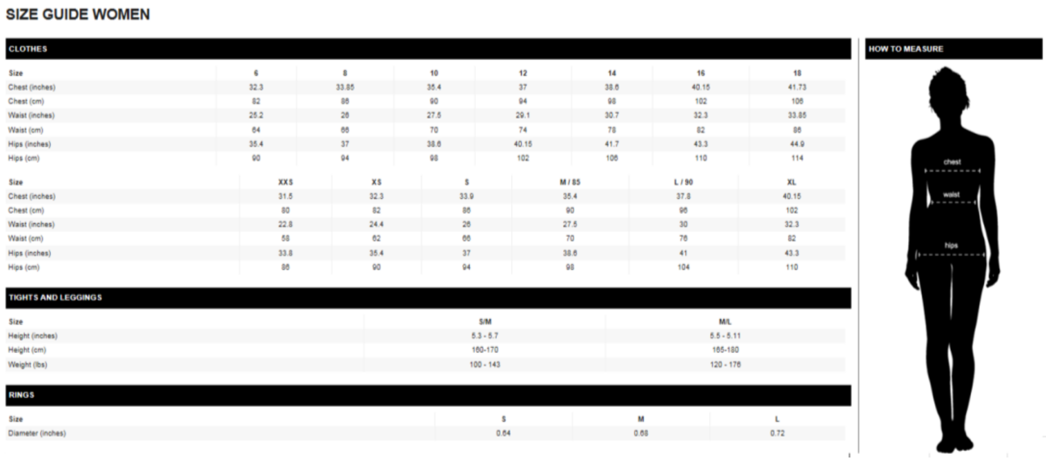
4. Trouser Length
Measure from inside leg bottom of the anklebone.

Your Guide to the Perfect Fit

• Jacket Length
Measure from nape of neck to he down centre back.

• Dress Length
Measured from nape of neck to hem down centre back to the hemline.

58 Zara


SIZE GUIDE WOMEN

CLOTHES

Size	6	8	10	12	14	16	18
Chest (inches)	32.3	33.85	35.4	37	38.6	40.15	41.73
Chest (cm)	82	86	90	94	98	102	106
Waist (inches)	25.2	26	27.5	29.1	30.7	32.3	33.85
Waist (cm)	64	66	70	74	78	82	86
Hips (inches)	35.4	37	38.6	40.15	41.7	43.3	44.9
Hips (cm)	90	94	98	102	106	110	114

Size	XXS	XS	S	M / 85	L / 90	XL
Chest (inches)	31.5	32.3	33.9	35.4	37.8	40.15
Chest (cm)	80	82	86	90	96	102
Waist (inches)	22.8	24.4	26	27.5	30	32.3
Waist (cm)	58	62	66	70	76	82
Hips (inches)	33.8	35.4	37	38.6	41	43.3
Hips (cm)	86	90	94	98	104	110

TIGHTS AND LEGGINGS

Size	S/M	M/L
Height (inches)	5.3 - 5.7	5.5 - 5.11
Height (cm)	160-170	165-180
Weight (lbs)	100 - 143	120 - 176

RINGS

Size	S	M	L
Diameter (inches)	0.64	0.68	0.72

HOW TO MEASURE

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20 Appendix L

20.1.1 Retailer’s Measurement Guidance Content Analysis Results

1	Retailer Measurement guidance content analysis					57 companies collated		
2	Image analysis							
3	Have images been provided as part of the guidance?							
4	images	written only	no visuals or written guidance					
5	38	16	3					
6	Type of figures used in images - details within the images							
7	Silhouette with no surface details	Manniquin	drawing with internal details	photograph of a real person				
8	6	4	17	11				
9	Figures dressed - Landmarks visable							
10	dressed in underwear	dressed in a dress	dressed in top and trousers	Nude	no internal details for LM			
11	15	6	5	5	6			
12	Posture of figures compared to scanning posture - all figures are standing front view only							
13	Static posture arms by sides	Static - arms not symmetrical	Static - hands on hips	dynamic - asymmetrical arms	slight side on	dynamic arms x body	dynamic - arms away from body	partical torso
14	12	3	5	9	2	2	2	3
15	Measurement inicators							
16	Placed on the figure	To the side of the figure	Not provided on or near image					
17	32	6	0					
18	Labelling of measurement lines							
19	labelled with LM area name	Labelled as a code	No labelling	Labelled with definition				
20	14	12	5	7				
21	Text analysis							
22	Key dimensions required							
23	Side neck point	Bust/chest	Waist	hips	garment length	inside leg		
24	3	53	51	50	12	29		

25	Bust definitions
26	Directly under-arm place tape measure at fullest part of the bust and across shoulder blades
27	Measure around the fullest part of the bust
28	measure around the fullest part
29	Measure around the fullest part of the bust
30	Wearing a bra, measure the strongest part of the chest
31	Place the tape measure under your arms and over your shoulder blades at the fullest part of the breasts. Remember to breathe out.
32	measure over the fullest position
33	measure over the fullest position and across shoulder blades
34	measure around the fullest part of your bust
35	measure around the fullest part of the bust making sure the tape is level at the back. The tape should be tight on the body.
36	measure the fullest part of the bust and around back
37	measure around the fullest part of the bust
38	Bust to be measured at the fullest part of the bust
39	measure around the fullest part of the bust and across the shoulder blades
40	Take the measurement around the fullest part
41	Measure at the fullest part of the bust
42	measure around the fullest part of the bust and around the shoulder blades
43	Wearing a bra measure around the fullest part of your bust
44	Take the tape measure across the fullest part of your bust and across the shoulder blades
45	measure across the fullest part of the bust ensuring the tape measure is straight across the back
46	measure the fullest part of your chest and across your shoulder blades
47	Take the tape measure under your arm and measure across the fullest part of the bust
48	wearing a bra take the tape measure across the fullest part of your bust
49	Take the tape measure around your body at the fullest part
50	Take the tape measure across the fullest point and across the shoulder blades

51	measure around the fullest part of the bust
52	measure around the fullest part of your bust and back
53	If possible, get a friend to help. With arms relaxed at your sides, measure the fullest part of your bust, keeping the tape parallel to the floor.
54	measurement taken by placing the tape measure snugly over the fullest part of the bust, around the back underneath the arms to form as straight a circumference as possible
55	measure around the fullest part of the bust and across the shoulder blades
56	measure around the fullest part of your bust and across your shoulder blades
57	Place the tape under your arms and measure around the fullest part of the bust
58	Place the tape measure under the arm and measure the fullest part of the bust
59	measure around the fullest part of the bust keeping the tape measure straight and taut
60	measure around the fullest part over the bust point
61	place the tape measure across the fullest part of the bust and across the shoulder blades
62	measure a full circumference around the fullest part of the chest or bust including the shoulder blades. Be sure to keep the tape measure straight and level
63	wearing underwear take the tape measure around the fullest part of the bust keeping the tape measure level at the back
64	measure around the fullest part and across the shoulder blades
65	only wear a simple bra and measure around the bust at fullest part, Make sure the tape is even at the back.
66	measure your body around the fullest part of the bust
67	measure around the fullest part of the bust. Be sure to keep the tape measure straight and level.
68	measure around the fullest part of the bust
69	Place the tape measure under your arm at the fullest part of the bust

70	Most common bust descriptions
71	fullest 47 times
72	across/around 29
73	shoulder blades 17
74	under wear 5 times
75	shoulder blades 17
76	tape measure straight/level 9
77	under arms 5
78	taut/tight/snug 3
79	bust point 1
80	most common written statement for bust measurement guidance/defintion contains: **tape measure around/across fullest point/part/area at underarms around/across shoulder blades with tape held level/parallel/straight**
81	scanner definition of bust measure: at the bust prominence taken as a level circumference line under the arms and around the torso

82	Waist definitions
83	to measure your natural waist place your hands just above your hips in line with your belly button, measure at this level
84	measure around your natural waistline keeping the tape comfortably loose
85	measure around the narrowest part of the waist
86	measure around the natural waistline
87	measure around the narrowest part of the waist
88	measure around your natural waistline. You can find it by bending to the side.
89	keeping the tape measure taut, measure around your natural waist - generally an inch above your belly button.
90	measure around your natural waist
91	measure around the natural waistline making sure to keep the tape measure taut
92	measure the slimmest part of the waist
93	waist to be measured around the natural waistline
94	measure around the waist keeping the tape measure taut
95	measure around the natural waistline
96	measure around the natural waistline keeping the tape measure comfortably loose
97	measure around the natural waistline
98	measure around the natural waistline which is the narrowest part of the waist
99	measure around the natural waistline
100	take from the slimmest part of your natural waistline
101	measure around the natural waistline keeping the tape measure taut
102	measure around your natural waistline
103	place the tape around the narrowest part of the natural waistline
104	measure around the slimmest part of your natural waistline - generally the part where your body creases when you bend slightly forwards or where you like to wear your waistbands
105	measure around the natural waistline
106	measure around your natural waist

107	wrap the tape measure around your body half way between the top hip bone and the bottom of your ribs. Breathe out naturally and take the measurement.							
108	measure around your waist in your underwear, at the point where your trousers would normally sit. Keep one finger between the tape and your body.							
109	measurement taken by placing the tape measure around the waist to form as straight a circumference as possible							
110	keeping the tape measure taut measure around the natural waistline							
111	measure around your natural waistline - generally an inch above your belly button							
112	measure around your natural waistline							
113	measure around your natural waistline							
114	measure around the narrowest part of your natural waistline - aim for above your navel and below your ribcage.							
115	tie a piece of string around the smallest part of your body and let it sit in a comfortable position - this is your natural waistline							
116	measure around the natural waistline keeping two fingers between the tape and your body							
117	measure a full circumference just above the natural waistline, again ensure the tape measure is straight and level.							
118	making sure the tape is not too tight and is level measure around your natural waistline							
119	measure around your natural waistline							
120	tie a length of string around your waist (this will be higher than you expect as it is the narrowest part). Now place the tape on the string this is how we define 'waist'. Below waist or low waist are approximately 2.5-5cm lower.							
121	measure your body around your natural waistline							
122	measure along the natural waistline (smallest part). Be sure to keep the tape measure straight and level.							
123	measure your natural waistline							
124	measure around your natural waistline							
125	Most common waist descriptions							
126	natural waist	narrowest/smallest	ref to ribs and hips	navel as LM	ref to measure value or other LM	ref to garment placement on body	bend body	string on waist
127	34	10	3	4	4	2	3	2
128	Measurement protocols							
129	tape loose	tape taut	level/straight measure	breathe out	underwear			
130	5	4	4	1	1			
131								

Comparison of Landmarks and measurment defintions

Measurement Name	Beazley and Bond (2004) definitions*	TC[2] definition (MMU mep)*	Landmarks used TC[2]	Landmarks used Beazley and Bond (2004)
Bust Girth (W102)	Taken horizontally around the fullest part of the bust and parallel to the ground incorporating the shoulder blades.	A horizontal circumference measurement taken under the armpits (without arms) and over the most prominent point of the bust. Maximum circumference of the trunk at the greatest bust prominence level	Greatest bust prominence, greatest forward bust projection.	Bust prominence, shoulder blades
Waist Girth (W108)	360 viewing. Using a waist elastic. Natural position of the waist, not parallel to the ground.	Side view of person. Find the deepest point of the spinal curve at the tangiental change place back waist landmark any any point within a 4cm tolerance to locate the narrowest point on the torso.	The small of the back/point of tangential change.	narrowest circumference in the waist region determined by the elastic method.
Neck Base Girth (W87)	Starting with the nape postion a close fitting chain around the base of the neck.	Measured at the transition of neck to trunk.	7th cervical vertebra, side neck the point of tangential change between the neck column and the torso, front neck point	Nape, sternal notch as implied by photo in paper.
Back Neck Depth (W12)	Given a standard measurement of 2cm, no definition in the book. Common in pattern literature as not an easy measurment to take	Distance between centre back neck level and right neck shoulder point level.	7th cervical vertebra, side neck the point of tangential change between the neck column and the torso	not explicitly specified
Back Neck -2-Waist Length (W40a)	The tape measure is positioned at the nape (7th cervical) and placed vertically down the centre back to thelower edge of the waist level tape	Distance between the centre back neck point and waist level. Contoured over shoulder blade then straight to waist.	Spinal process of cervical vertebrae at the base of neck small of back and waist	natural waist level, 7th cervical
Armhole Depth/Scye Depth	Locate the nape of the neck and run a tape straight down the centre back Locate the bottom of the armpit and run a tape horizontally across the back until it intersects the vertical tape. Read the measurement.	Derived measurement. Vertical distance from the level of the Centre Base Neck straight to the arm base level. Arm base level /armscye underarm level: horizontal line passed under the armpits at the level of the underarm midpoint. Distance between right armhole long shoulder point and right underarm level.	Centre Base Neck and armpit level. Axilla. Acromion extremity	Nape of the neck, armpit bottom. Not specific only provides a picture.
Side Neck 2 Waist (over the bust)	Tape measure is positioned from the nape over the right shoulder at the neckline, then diagonally to the prominence of the right breast continuing downwards to the waist level. Half the back neck measurment is subtracted from this measurment	Derived measurement. Locate the R side neck point, move over the body contours in a diagonal trajectory ending at the most prominent part of the R breast, then virtually straight to the waist level.	Upper Trapezius muscle, Nipple, Under Bust level (rib cage) and waist level	C7, Nape, bust prominence, waist level
Side Neck to Bust	Tape measure is positioned from the nape over the right shoulder at the neckline, then diagonally to the prominence of the right breast. Half the back neck measurment is subtracted from	Distance from the base of the neck (shoulder neck point) to the breast point Measured from the neck shoulder point on the	Shoulder neck point and breast point.	C7, Nape and bust prominence
Across the Back (W83)	A width measurement taken horizontally and gauged just above the skinfolds where the arms connect to the torso	Across Back Width. The width taken between the back left and right armpit points Contoured surface length (W83)	Back left and right armpit points.	axillia fold

	Comparison of Landmarks and measurment defintions				
	Measurement Name	Beazley and Bond (2004) definitions*	TC[2] definition (MMU mep)ᵞ	Landmarks used TC[2]	Landmarks used Beazley and Bond (2004)
J	Across the Front (W85)	The measurement is taken horizontally between the left and right skin folds where the arm connects to the torso. This is approximately midway between the centre front neck point and bust level.	Horizontal distance between the front armholes on the across front level – 2/3 of the depth of the armscye from the shoulder point level. Depth between the shoulder arm point and the underarm	1/3 of front armscyes height above the armpit	under arm level, neck point and fullest girth of the bust
K	Shoulder Length (W91)	The highest part of the shoulder is located and measured from the base of the neck to the bone at the end of the shoulder.	Distance from the base of the neck (shoulder neck point) to the shoulder point (acromion extremity) Measured in a straight line	Shoulder neck base point and acromion extremity	acromion-clavicular, position at the base of the side neck
L	Bust Prominence width , bust point distance (W86)	Measure horizontally between the most prominent part of the left and right breasts	Horizontal distance between the bust points.	nipples	bust prominence
M	Width of Armhole/scye width (W97)	Scye width, taken using calipers (Beazley, 1996). No information within the book.	Horizontal distance between the body contours of the upper arm viewed from the side Measured at the underarm midpoint level	Arm base at the transition to the trunk front and back in level of the armpit	not explicitly specified either in the book or in an early academic paper by Beazley (1996)

* definitions are from: Beazley, A., & Bond, T., (2003), *Computer-Aided Pattern Design & Product Development* , Blackwell Publishing, Oxford; Beazley, A., (1998), Size and Fit: Proceedures in Undertaking a Survey of Body Measurements, *Journal of Fashion Marketing and Management* , 2 (1), pp. 55-85

ᵞ defintions are from: The TC[2] scanner database via the edit point facility; and Kirchdoerfer, E., Treleaven, P., Douros, I., and Bougourd, J., (2002) *Proposed Human Body Measurement Standard* , (online)

21 Appendix M

21.1 Table of Landmarking methods

Landmarking Methods Table

Landmarking Method	Method name & subject/researcher/software involvement	Used in which study	Anatomical positioning	Protocols for implementation	Used for Identifying which landmark	Skill set needed to implement	Landmarking methods relationships & combination	Landmarking method accuracy	Critique
Automatic. A pre landmarked deformable template is placed over the region of interest.	Function fitting, requires little engagement with the scan subject. and much of the work is done after the scan is completed.	Suikerbuik et al, 2004	Natural standing position only.	Subject is scanned. The scans are then sorted into shape categories. The scans are divided up using bounding boxes into areas of interest. These areas have point subset configurations which denote a specific type of skin surface terrain in which the landmark is present. This template is not rigid due to a different similarity function which allows the template to deform within set tolerances determined by a Gaussian distribution function (Appendix J). The landmark is at the peak of the distribution and tolerances are set either side of that distribution arc The parameters of the distribution function are estimated by non-linear regression, so that the distribution function will resemble the region of interest." (suikerbuik et al, 2004) The lowest value signifies the best fit.	Sellion (Appendix D Glossary of terms) and medial malleolus (Appendix D Glossary of terms) for this study. It is possible to use for other landmarks but the more visible the landmark the more accurate the method is.	Anthropometric training and an in-depth understanding of 3D computer graphics and geometry.	**Strong relationship** with other automatic methods in that it does not need operator intervention. **Weaker relationship** with semi automatic methods as landmarks are predetermined on the template by a human operator.	Accuracy levels are if the subject moves or the scan image is not clean of enough noise. A large library of templates is needed to closely match each subject. Only tested on sellion and malleolus which have a visually apparent surface terrain.	Not tested on females over 55 years of age.Manipulation of the method requires skills in computer science and therefore is not suitable for a clothing practitioner who is not required to possess those skills.

Manual and automatic. Palpation, observation and physical marking with small cones. Interaction with the software to extract measurements using the digital tape measure. The tape measure uses recreated surface geometry	Semi-automatic measurement method. Part of the measurement method is accomplished with the subject being present, part of the work is accomplished by researcher engaging with the software and part of the work is done automatically.	Chi & Kennon (2006)	Natural and Dynamic postures of front and back upper torso and limbs	Subjects wear only briefs. Researchers manually palpates subject to locate selected landmarks. Landmarks are physically marked with small cones. Cone were used for their ability to show on the scans from the Vitus 3D laser scanner. Subject is placed inside the scanning booth and were verbally and physically instructed to place their limbs into specially design jigs. The subject was scanned with the lasers from 4 columns situated inside the scanning booth. The ScanWorX software allowed the researcher to extract the measurements from between the pre-marked landmarks using a digital tape measure. These measurements were collected for analysis.	Landmarks of the upper torso and arm (see attached comment box)	Understanding anatomy. Training to an expert level in observation and palpation techniques. Ability to understand and develop specialist measuring jigs. Training in 3D body scanning protocols. Training in the utilisation of ScanWorX software's digital tape measure.	**Strong relationship** with manual techniques in that the landmark location and marking are similar. Although the marking material differs as the scanning equipment requires raised markers to be enabling visibility on the scanned image. The use of the digital tape performs a similar function to a traditional tape measure in that it is a measuring devise which is drawn across two or more landmark points. Can be combined with manual anthropometric preparation techniques.	Precision is lacking due to the ScanWorX software underestimating the convexity of skin surface curvature. The size of the cone markers and the skill of physically placing the digital tape measure between these markers introduced errors in measurement values. Researchers concluded this method of measuring was not accurate enough for clothing pattern development.	Limited in the sample size and did not include females over 55 years of age. A useful attempt at utilising 3D scanning technology to capture measurements from dynamic posture.

Requires a 3D scanner. Automatic, match a surface of which all relevant information is known (a template) onto another surface (suikerbuik et al, 2004). Follows the principles of image or shape recognition. A template is developed using similar shape body parts which also share a similar point cloud configuration. There is a great deal of preliminary work to be done for this method as many different shaped templates need to be developed.	Template matching much of the work is done after the subject has been scanned.	Suikerbuik et al, 2004	Natural standing position	There is preparatory work to be done before the templates can be applied. Scans are segmented into areas of interest (landmarks) in readiness for the template to be made. Templates are developed from these scans. These scans will have similar point patterns (similar shape) and the landmarks will appear in a similar region. The template will be developed from a small subset of points containing the landmark. This information is held within a bounding box. Location of this bounding box on the body is stored as a written directive by the operator, so the software knows the origin of the point subset. Using euclidian distance, an algorithm (similarity function) is developed to determine the best template fit around the segmented body part between the template and the scan points. Once the templates and similarity function were developed the method was automated.	Sellion and medial malleolus for this study. Can use for other LMs but the more visible the LM the more accurate the method. ie accuracy was greater on the malleolus (ankle bone) on the outside of the foot. This bone protrudes & has little fat in that region. Less accuracy on the sellion (mid point between eyebrows). This is perhaps because of more variety in nose shape and trajectory.	Knowledge of anatomy theory. Training in writing computer software.	**Strong relationship** with any method that uses vectorised skin surface analysis.	Accuracy levels depend on the amounts of templates available within the software.	Individual scans can produce variable amounts of points within the point cloud so it is difficult to match up subjects to templates if there is a variation in the point cloud configuration and density.

Initial manual human palpation to locate and physically mark subject's landmarks with stick on markers. Location of the marked landmark is achieved in two ways. First the marked landmark is located via it colour and vector shape formation so the software is looking at both mathematical points in 3D space and colour voxel formations (the software wants to find the clear white centre of the marker). Second the marked landmark is cross checked via a heuristic rule which is a written directive algorithm containing the name and a very comprehensive definition of the landmark (. Finally the landmark location and name are verified and validated using another software package which can use comparative values called a heuristic check (measurement of less or more than) to establish relationships between landmarks thereby providing greater accuracy in the final location and name of the specific landmark. This heuristic check cannot correct landmarks automatically but alerts the operator to erroneous landmarking thereby offering the operator a chance to correct or document errors. document	Semi-automatic measurement method. Part of the measurement method is accomplished with the subject being present. Part of the work is accomplished by researcher engaging with the software and part of the work is done automatically. The approach was to manually mimic an automatic point detection process using human operators and once the accuracies are with an acceptable tolerance percentage the process is automated (Burnsides et al, 2003).	Somewhat similar to Geisen et al's (1995) previous semi automatic methods. Was developed for the CAESAR survey.	Standing position with held arms away from the sides of the body.	Subject numbers or selection criteria not discussed. Manual palpation is used to locate landmarks and markers are applied. The markers shape and dimensions vary depending on the visibility of the landmark to the scanners cameras. So for areas difficult areas such as the crotch point, (Zhong & Xu, 2006, Nu & Zhang, 2009) "a white rubber object approximately 10mm square at the base, 7mm square at the top and 6mm high was chosen for these landmarks" (Burnsides et al, 2003, 394). 12 landmarks were labelled up with these style of markers (Burnsides et al, 2003). All other landmarks which are clearly visible to the scanners cameras were labelled with 12.5mm white dots (Burnsides et al, 2003). Landmark extraction was broken into 3 categories: 1 detection of candidate points, 2 identification of each candidate as a specific landmark or non landmark and 3 verification to determine if the resulting landmark sets are correct and complete (Burnsides et al, 2003). 1st stage the human operator views the colour file image and manually clicks on the white markers. They zoom in to find its centre and a ring is placed around the centre point of the marker to notify the operator that the landmark has been located and selected (Burnsides et al, 2003). This operation is repeated until a landmark set is established. Once collated the landmark sets from each subject are automatically aligned and merged into a single data set which converts the detected landmark positions to 3D coordinates (Burnsides et al, 2003). Stage two involves a reliable method of matching the located landmarks with it's landmark name (Burnsides et al, 2003). This is a two step process. The first step involves body segmentation into 6 sections (head, torso, 2 arms and 2 legs) and each of these sections has a neutral net applied to that section to provide preliminary automatic landmark identification (Burnsides et al, 2003). The neural net was developed using The Learning Quantization Program Package Version 3.1 which suggests the system 'views' the landmark areas via the vector structures. This means the software is tracking the either point cloud or polygonal mesh surface shape to detect surface patterns which are common among the landmark data sets from different subjects. The software also examined the voxels colour/luminosity to identify the whitest part of the markers placed on the landmark. The second step increased Landmark location accuracy by using a set of heuristic rules which were also applied to the neural net. This was necessary for landmarks which lie in close proximity. The heuristic rules were written comprehensive directives which detail landmark position and name. The name and position were cross referenced with ISO 7250 although CAESAR predominantly used its own definitions as this standard does not distinguish between left or right (Blackwell et al, 2002)	Whole body. Paper shows images of a subject whose head, arms and torso have been landmarked.	Training in manual palpation and marking of anatomical landmarks. If the software is not already set up a detailed knowledge of vectors, statistics and computer software writing is needed. If software is already set up all the operator needs to assess is if all markers are present in the scanned image. Knowledge of landmarks names.	**Strong relationship** to manual methods whereby the operator has to visually assess and then palpate the skin surface to locate the landmark. **Weak relationship** to template matching as this initially involves operator engagement in the development of placing the landmarks within the templates. **Weak relationship** to feature discriminate functions rely on operator derived descriptors of the skin surface some thing which would be found in a manual anthropometric survey manual. No relationship to statistical analysis.	Reported as being good for all landmarks (Robinette & Harrison, 2002, Robinette *et al*, 2002; Burnsides *et al*, 2003) as there was no reliable automatic landmarking method developed at the time for the CAESAR survey. The data from this survey has been used in other studies due to its reliability	Survey only scanned subjects up to age 65 (Robinette et al, 2002) so it cannot be assumed that this method is suitable for the body morphology of female subjects over 65. This method is reliant on operator diligence in the palpation, marking and scan assessment phase. Many papers, including Burnsides et al (2003) have stressed human error particularly at the initial stages. The sizes and shapes of subjects are not discussed and the visual information shows a younger woman with a standard body shape and posture. As this survey was for a whole population it can be presumed that a variety of demographics, body sizes, shapes and genders were used to gather the vital landmarking data. However to repeat these methods information such as this should be explicit.

Manual method implemented by a human agent who has been given training (unspecified time limited) in landmark identification, location/selection and application of measuring equipment, taking and recording data. Manual using visual analysis of the body, palpation of the skin to locate skeletal landmarks. Demarcation of landmarks uses a variety of methods including, skin marking pencil, pins and dowels.	Traditional manual measurement fixed and hand held equipment. Subject and operator engage with each other as operator directs the subject into different measurement positions.	O'Brien and Shelton (1941). First study to collect female anthropometric data for the clothing industry (Fan et al, 2004)	Natural standing position, sitting position and dynamic posture for measurement of arms and legs.	Subjects are first landmarked using visual analysis of the skin surface and tactile analysis of the skin surface terrain. Once landmarks are found they are marked using a suitable skin marking medium. Subjects are then measured by a human operator using a variety of fixed or hand held measuring instruments. Subjects are required to listen to directions and adopt predefined postures for particular measurements. Measurements are taken and recorded by the operator.	Used to mark measurements suitable for clothing design and development.	Knowledge of anatomy theory. Practical experience in landmark detection and location.	**Strong relationship** to semi automatic landmarking methods as both use visual and tactile analysis of the body to locate and place the landmarks. **Weak relationship** with any method which scans the vectorised skin surface to find areas of interest which surround the landmark.	Accuracy is reliant on the skill and concentration of the operator.	Uses mixed nomenclature for the landmarks i.e. acromion is used alongside shoulder point. Landmarks are not explicitly described and diagrams are a little busy so difficult to see exact point of landmark location. Study only had 2% of subjects aged 65+
This method constructs computer functions via neural networks to characterise and search features individually over the body surface. The function requires descriptions of local feature attributes along the skin surface terrain so landmarks can be located within the local feature attributes.	Automatic Feature discriminent functions. Subject is scanned and this function works during the vectorisation (Appendix D)of the captured bitmap image. There is no interaction between the subject and the method.	Discussed in Dekker *et al,(* 1999)	Not stated although all images used within the publication are shown in the standing position with held arms away from the sides of the body.	Subject is scanned and the digitised skin surface is cleaned and smoothed. Body model is skinned to provide a base using either B-spine or polygonal primatives. Functions are written by human operators into the software to characterise and search for body features individually. The functions are developed using shape descriptors which are viewed by the software in the context of whole body attributes. These functions can detect relevant body features and primary landmarks such as branching points in the armpits and crotch. The function then goes on to detect more subtle landmarks using the branching points as a context for subsequent detectors.	whole body	Training in anthropometrics and 3D computer imaging	**Weak relationship** with manual and semi automatic methods as all use visual analysis of the skin surface terrain to assess its characteristics for clues to landmark location. **Strong relationship** with other automatic methods as it uses 3D geometrics to evaluate skin surface terrain.	Only as good as the landmark definitions used within the descriptors.	There is some critique of the method within this paper in the form of comparative analysis between this and another similar automatic method (Global deformable templates). However the paper is largely descriptive and its sample set does not contain individuals within the very obese BMI category and is therefore not truly representative of the whole UK population.

Automatic method. The method is based on learning landmark attributes and their spatial relationships between other landmarks from a set of human scans.	Statistical analysis and statistical learning algorithms. No integration with scan subject. No integration with the scanner operator.	Azouz *et al* , (2006)	They used CASEAR data which did include subjects in sitting positions. However their research only used the data from the subjects in a standing position with held arms away from the sides of the body.	Scan data is needed. An algorithm is formulated by looking a scans of male subjects who display different body sizes and shapes. The scans are prelandmarked and values between these areas are extracted and statistically analysed to form a landmark graphic of average distance and most likely neighbouring landmarks using a statistical imaging tool called a pairwise Markov random field.	Whole body. Paper shows images of a subject whose head, arms legs and torso have been landmarked.	Knowledge of statistics and 3D graphics is needed to develop or amend the method. As this study used secondary scan data a knowledge of landmarking was not needed. A clothing practitioners would not have the skill set to implement this method.	**Strong relationship** with Feature discriminate functions as both methods scan the vectorised skin surface to look for surface characteristics of or around the landmarks. **Weak relationship** as skin surface terrain is visually evaluated for areas of interest.	Shown to be more accurate and more objective than semi automatic methods. However the method was only undertaken on male subjects so it would need to be tested on female subjects of different ages and body sizes/shapes.	Used males subject only so it is doubtful if it would be effective for females over 55+.

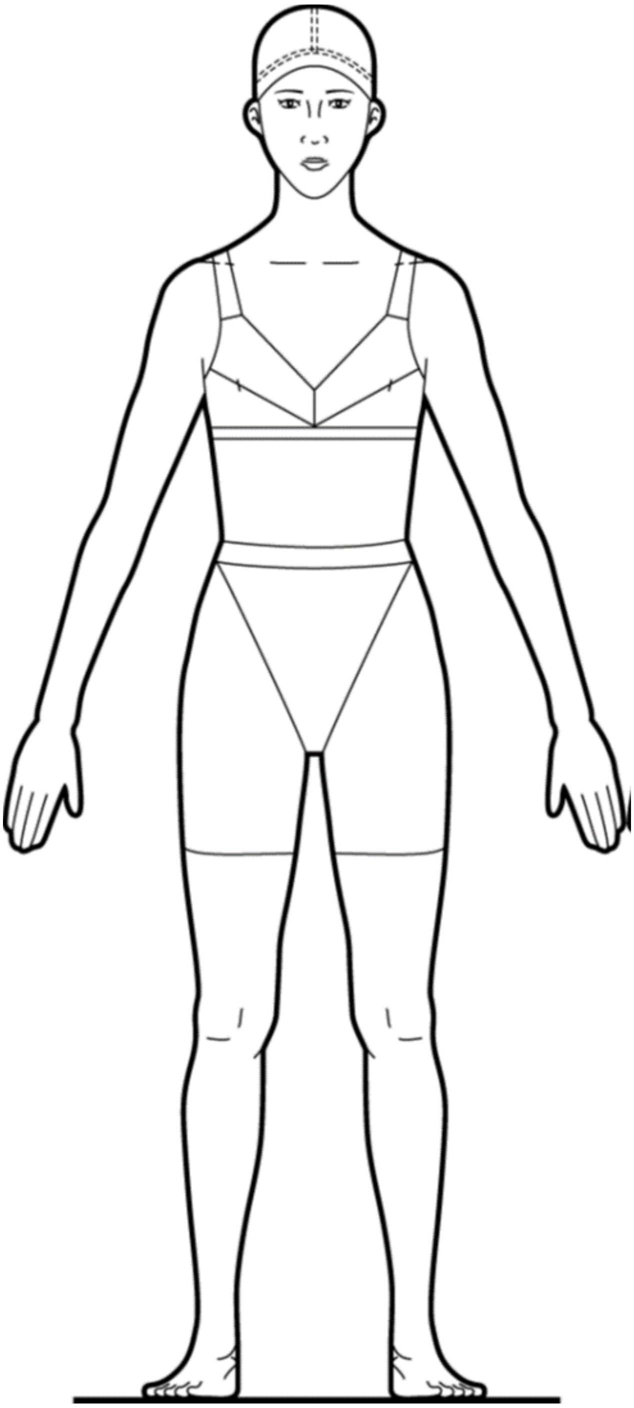
Automatic. Pre landmarked part mesh templates are developed and written in C++ (Appendix D Glossary of terms).	Template matching much of the work is done after the subject has been scanned. To match each template to each body part	Yoon *et al*, 2009	Standing position with held arms away from the sides of the body.	requires a subject to be scanned. The raw data is cleaned and skinned. The body model is decomposed into 16 segmented parts. The surface terrain is scanned and pre landmarked part meshes are matched to each of the 16 portions of the body using correspondence in terms of the geometric attributes on the mesh and on the body model. The landmarking is best on a best matched approach.	whole body	knowledge of anthropometrics and a working knowledge of computer science and programming.	**Strong relationship** with other automatic methods in that it does not need operator intervention. **Weaker relationship** with semi automatic methods as landmarks are predetermined on the template by a human operator and the surface terrain is scanned by the programme in much the same way as a human operator would scan the skin surface.	Mean landmarking error reported as 1.34cm and compared to traditional methods reported as 1cm. Therefore it is not as accurate as traditional methods. There is scope for this method to be used on different body morphologies as it uses a part mesh thereby giving more flexibility.	It appears to have used male subjects only as all the images used are male and there is no reference to nipple or bust point in the list of average landmarking errors so it is doubtful however accurate this method would be for females over 55+ with altered body shape.

Automatic. Geometric surface evaluation using statistical analysis. Averages heights of landmarks from the floor are calculated and compared between landmarks. These averages are calculated from different groups of scans. Indeed the method relies on scans being grouped into 'body shape factors'. The factors use particular criteria to describe them eg subjects how display excessive fat deposition around the thigh region are grouped by BMI for the location of the crotch point.	A combination of skin surface evaluation via the geometric characteristics around the landmark site; and statistical analysis of most likely neighbouring surface shape. There is no subject involvement as the data was used from the Size Korea survey which was undertaken prior to this research.	Han *et al* , 2010	Standing position with held arms away from the sides of the body.	This method requires scan data. Specific areas on the body model were targeted (areas for measurement which have been previously manually pre-defined as necessary to collect anthropometric data). The contour was viewed as a series of slopes which were evaluated in terms of their depth and direction. Positive and negative values were assigned to the slopes and the landmark was determined at a particular point in the either positive or negative value. This method is developed as an algorithms which essentially assesses the geometrical characteristics of the digitised skin surface terrain. Landmarks are written into the algorithms as descriptions of the geometric skin surface and are not reliant on manual landmarking definitions.	Bust point (nipple), waist, abdomen and hips.	Mainly requires in-depth knowledge of computer science and mathematics, particularly geometry and statistics. The process does require anthropometric knowledge in terms of knowing the landmark and measurement definitions. The	It does not require a knowledge of palpation, only visual analysis of the skin surface therefore it share a **weak relationship** with manual and semi automatic methods. It does require knowledge of computer programming and mathematics (particularly statistics and geometry) so it a **strong relationship** with other automatic methods.	Has been validated on a variety of body sizes and shapes, however it is unclear if subjects from the obese and very obese BMI categories were used in this study as only average BMI's were stated. Until these categories have been specifically tested it unclear if it will accurately locate landmarks on bodies of this type.	Grouping subjects into the body shape factors does take considerable time. This can have to effect of negating time savings at the scanning stage. The method also relies on scans from another study using the measurement definitions that were pedetermined for that study. This means arrors from the previous study maybe inadvertently carried into this study. The sutdy is very useful in that is clearly indicates how 3D scanning technology operates in terms of how the software scans the surface terrain

A semi automatic method which requires partial user intervention. The user observes the scanned image and extracts measurements from it using pre-determined commands written in C++.	A virtual tape measure which can be placed on or along point configurations. This system, uses landmark defintions via the operators empirical knowledge.	Pargas *et al*, 1997	Standing position with held arms away from the sides of the body.	Requires a scanned body model. The body model point cloud configuration appears to be represented as a series of rings or slices. Pathways are selected along or through the slices/rings and the software then extracts the measurement of the pathway. The pathway can travel in the X,Y or Z direction so lengths depths and circumferences can be established. Macros are then generated using these developed pathways so the method can be automated.	Torso region including the arms, crotch and low hip region.	Building the system requires the skills of a software engineer. Using the system accurately requires the skills of an anthropometric or clothing practitioner	**Strong relationship** with manual methods as accuracy of measurement placement is dependant on level of skill in anthropometrics. **Weak relationship** with automatic methods, as though reliant on the software to implement the measurement extraction this method will only work with operator invention at the beginning.	The method requires a highly skilled anthropometric practitioner to assess and develop the measurement pathways initially. Many measurement pathways need developing for different body shapes and morphologies to be truly accurate.	A simple method which can be easily comprehended by clothing practitioners. The method offers flexibility as the user can decide where to take a measurement from and is not bound by hardwired landmarks. The system is not reliant on pre-determined landmark s.

22 Appendix N

22.1 Extracts from BS EN ISO 20685:2010 3-D scanning methodologies for internationally compatible anthropometric databases.



A list of standard landmark definitions taken from BS EN ISO 20685:2010

3.13
glabella
Most anterior point of the forehead between the browridges in the midsagittal plane
[ISO 7250-1:2008, 2.2.9]

3.14
iliocristale
Most lateral palpable point of the iliac crest of the pelvis
3.15
infraorbitale
Lowest point on the anterior border of the bony eye socket
3.16
lateral malleolus
Most lateral point of the right lateral malleolus (outside ankle bone)
3.17
lowest rib
Inferior point of the bottom of the rib cage
3.18
menton
Lowest point of the tip of the chin in the midsagittal plane
[ISO 7250-1:2008, 2.2.16]
3.19
mesosternale
Point on the union of the third and fourth sternebrae
[ISO 7250-1:2008, 2.2.17]
3.20
opisthocranion
Most distant point from glabella in the midsagittal plane
3.21
point cloud
Collection of 3-D points in space referenced by their coordinate values
NOTE A point cloud constitutes the raw data from a 3-D scanner and needs to be translated to a human axis system.
3.22
radial styloid
Protuberance of the radius at the wrist
NOTE Adapted from ISO 7250-1:2008, definition 2.2.26.
3.23
repeatability
Extent to which the values of a variable measured twice on the same subject are the same
3.24
sellion
Point of greatest indentation of the nasal root depression

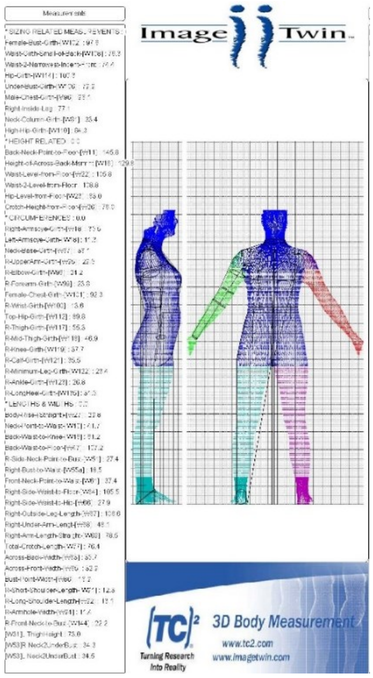
23 Appendix O

23.1 Body Scan information sheet and process

The body scanner provides a unique opportunity for you to have your body captured in 3D and for measurements to be extracted. This data can be used to create an avatar to your dimensions and to classify your body shape. You may also like to return to the scanner to record any body size/ shape changes over a longer period of time.

Sample Scan Measurement Output

Scanning process:



- On arrival you will need to complete a consent form and the scan process will be explained
- Using a private changing cubicle, you will undress down to your underwear then don a dressing gown.
- Prior to scanning a number of manual measurements will be taken.
- You will then enter the private scanner booth, close the curtain and remove your dressing gown
- Your scan will be captured and once processed you will leave the booth in your dressing gown to get dressed.
- A copy of your scan and list of measurements will be provided.

What should I wear:

- Underwear should be close fitting and Not Black or shiny fabric, as they will cause data loss in the scan. Most suitable colours are beige, grey, light blue (NX16 model only).

Women - close fitting bra and briefs in

Men - close fitting briefs.
No loose fitting boxer shorts

Jewellery and hair:

- Stud earrings may be worn
- No bracelets, long earrings, watches or glasses
- Long hair must be tied up away from the neck.

Ethics:

- Subjects can withdraw at anytime from the scan process without reason
- Data will be kept privately and will be anonymous (scans are individually coded)
- Scan images will be used anonymously for research and teaching at MMU
- Two technicians will be present during the scanning process

More details of the scanner can be found at

http://www.hollings.mmu.ac.uk/bodyscanner/

Process for capturing scans (process documented by S.Gill and A. Panchenko (2013)

Key considerations of capturing scan data.

- A minimum of two trained body scanner staff must be present during the scanning process to ensure clear ethical procedures are followed and for the comfort of participants.
- A record of both trained staff should be retained during the collection of participant consent
- The subject should sign a consent form containing full details of the process, reasons for data collection and what is being consented to regarding their data and its use:

  [I voluntarily consent to my body scan being captured and stored for the purpose of future research and teaching at Manchester Metropolitan University. I understand anonymous scan data may be passed to organisations outside of the University, e.g. clothing manufacturers.]

- All individual scans should be coded using a system that does not directly identify the participant, it is recommended that a sequential numbering system is used and that scan names include a character which indicates the participants gender (usually M or F).

[Example of code: 0001MA35, 4 digits sequential number, Gender, Ethnicity Code, Age]

- All data should be stored securely. Personal information stored in a database should be protected with a password and care should be taken to ensure data that is defined as a protected characteristic is stored according with recommendations of the data collection act.

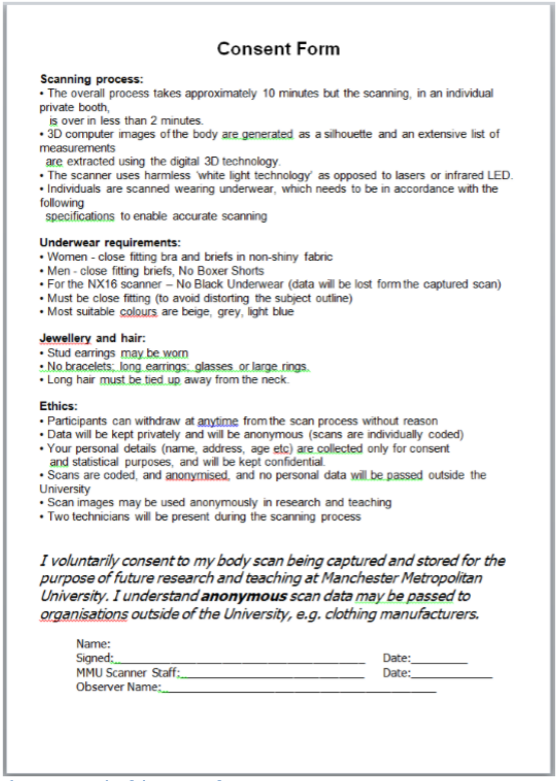
Inventory for collecting body scans:

- ✓ Body scanner
- ✓ Scanner PC
- ✓ Printer
- ✓ Stadiometer (for recoding height to the nearest millimetre)
- ✓ Scales (for collecting weight to the nearest 100gms)
- ✓ Changing cubicles
- ✓ Dressing gowns
- ✓ Hair ties
- ✓ Tape measure (for any further manual measurements)

Consent forms for body scanning

Before being scanned, each participant must sign the consent form, this is the record which constrains use to those items the participant has agreed to. The consent form should also be signed by the staff member who captures the scan and the observer (any other staff member present during the process).

The consent form should contain a brief description of the scanning process, the ethical issues and the consent statement itself (see an example below).



Consent Form

Scanning process:
• The overall process takes approximately 10 minutes but the scanning, in an individual private booth,
is over in less than 2 minutes.
• 3D computer images of the body are generated as a silhouette and an extensive list of measurements
are extracted using the digital 3D technology.
• The scanner uses harmless 'white light technology' as opposed to lasers or infrared LED.
• Individuals are scanned wearing underwear, which needs to be in accordance with the following
specifications to enable accurate scanning

Underwear requirements:
• Women - close fitting bra and briefs in non-shiny fabric
• Men - close fitting briefs, No Boxer Shorts
• For the NX16 scanner – No Black Underwear (data will be lost form the captured scan)
• Must be close fitting (to avoid distorting the subject outline)
• Most suitable colours are beige, grey, light blue

Jewellery and hair:
• Stud earrings may be worn
• No bracelets; long earrings; glasses or large rings.
• Long hair must be tied up away from the neck.

Ethics:
• Participants can withdraw at anytime from the scan process without reason
• Data will be kept privately and will be anonymous (scans are individually coded)
• Your personal details (name, address, age etc) are collected only for consent
and statistical purposes, and will be kept confidential.
• Scans are coded, and anonymised, and no personal data will be passed outside the University
• Scan images may be used anonymously in research and teaching
• Two technicians will be present during the scanning process

I voluntarily consent to my body scan being captured and stored for the purpose of future research and teaching at Manchester Metropolitan University. I understand ***anonymous*** *scan data may be passed to organisations outside of the University, e.g. clothing manufacturers.*

Name:
Signed:________________ Date:________
MMU Scanner Staff:________________ Date:________
Observer Name:________________

Example of the consent form

Collecting participant's details

It is recommended all the following details are collected during the scan process and stored in a suitable database:

Participant's code

Name
Age
Gender
Ethnicity
Height
Weight
Address
Contact details

These details can be used to form the basis of a participant code for anonymous storage of captured scan data. [Example of code: 0001MA35, 4 digits sequential number, Gender, Ethnicity Code, Age]

Name should be typed in by the participant themselves to avoid misspelling.

Address in the form of a postcode is collected to allow analysis of the distribution of different body shapes and sizes within the UK geography. In this respect, if the participant does not want to provide the full address, the first part of the postcode should be recorded.

Contact details in the form of an email address can be recorded if the participant is interested to hear about further body scanning projects.

Ethnicity should be chosen by the participant from the list provided (4.1). Ethnicity is a protected characteristic according to the data protection act and it should be coded for storage and processing.

Participant Code	Gender	Ethnicity	Age	Forename	Surname	Postcode	Email	Height	Weight
0001	M		24	Joe	Bloggs	SK1 7HG		178.5	76.56
0002	F		67	Jane	Doe	NG7 6FG			
0003									
0004									
0005									
0006									

Figure 2: Example of an Excel sheet for capturing scan details

Any other characteristics can be collected optionally.

Ethnicities list and coding Ethnicity codes are based on the national codes for ethnicity used by the NHS and document in 2004. Within the database and the coding, ethnicity can be recorded using the first letter of the code.

Codes Used	Original Codes
W British	White A British B Irish C Any other White background
D White and Black Caribbean E White and Black African F White and Asian G Any other mixed background	Mixed D White and Black Caribbean E White and Black African F White and Asian G Any other mixed background
L Asian	Asian or Asian British H Indian J Pakistani K Bangladeshi L Any other Asian background
P Black	Black or Black British M Caribbean N African P Any other Black background
R Chinese	R Chinese
S Any other ethnic group	S Any other ethnic group
Z Not stated	Z Not stated

Codes Used Original Codes W British White A British B Irish C Any other White background D White and Black Caribbean E White and Black African F White and Asian G Any other mixed background Mixed D White and Black Caribbean E

White and Black African F White and Asian G Any other mixed background L Asian Asian or Asian British H Indian J Pakistani K Bangladeshi L Any other Asian background P Black Black or Black British M Caribbean N African P Any other Black background R Chinese R Chinese S Any other ethnic group S Any other ethnic group Z Not stated Z Not stated

Participant Code Gender Ethnicity Age Forename Surname Postcode Email Height Weight 0001 M 24 Joe Bloggs SK1 7HG 178.5 76.56 0002 F 67 Jane Doe NG7 6FG 0003 0004 0005 0006

Scanning Dress Requirements

While being scanned, participants should be wearing underwear only. However at all stages other than in the scanner they should be wearing dressing gowns.

Underwear to be worn during scanning:

Participants should be wearing close-fitting underwear (for males: tight boxers or briefs; for females: tight pants and their regular bras). Please no corsets and correction underwear unless the participant wears it all the time. Please no loose underwear (loose boxer shorts, singlets, t-shirts) and no socks.

Hair and jewellery

The participant's hair should be tied up as high as possible to remove any loose hair from neck and shoulders, which may interfere with the outline of scan and interfere with accurate measurement extraction. Participants should be offered hair ties, clips and nets if needed.

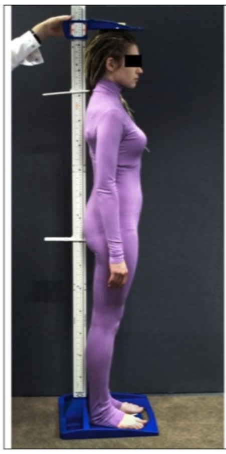
Any large jewellery (watches, bracelets, earrings) should be taken off.

Changing

To make the changing process more comfortable and to ensure compliance with ethical considerations participants should be taken to a private changing cubicle and asked to undress to their underwear and to put on a dressing gown.

Taking manual measurements

When the participant has changed, manual measurements (height and weight) should be taken Height and weight must be taken from each participant and recorded in the participant database and if practical embedded with the scan.



HEIGHT

Subject stands on the stadiometer with heels to the back, weight evenly distributed, feet together and arms relaxed at the sides, the head should be in the Frankfort plane, with the top of the ear canal level with the base of the eye sockets.
Measurer checks the subjects posture and locates the vertex of head with one hand then lowers the measuring plate to this point, compressing the hair to ensure a correct height reading. Height should be recorded in centimeters and millimeters.
[Measurement definition S.Gill 2013]

WEIGHT

The subject wearing minimal garments steps onto the scales and stands still in the centre of the measuring platform, with weight evenly distributed on both feet. The measurement is read one the reading becomes stable. The weight of any clothing (dressing gown) should be subtracted (it is recommended that standard gowns are used, and their weight is established beforehand). Weight should be recorded in kilograms and grams.
[Measurement definition S.Gill 2013]

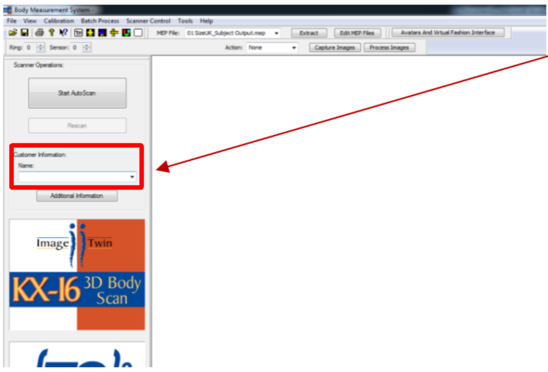
If any extra measurements are taken, their definitions and the process of measuring should be documented in detail to guarantee the consistency of the study.

Capturing scans

The following process documents the capturing of the scans.

Completing the scan code

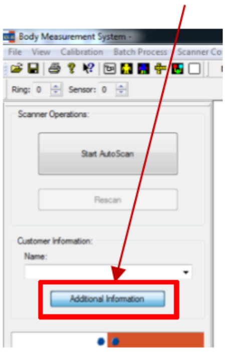
When the participant is taken to the scanning cubicle, input their code to the NAME field of the KX scanner software.



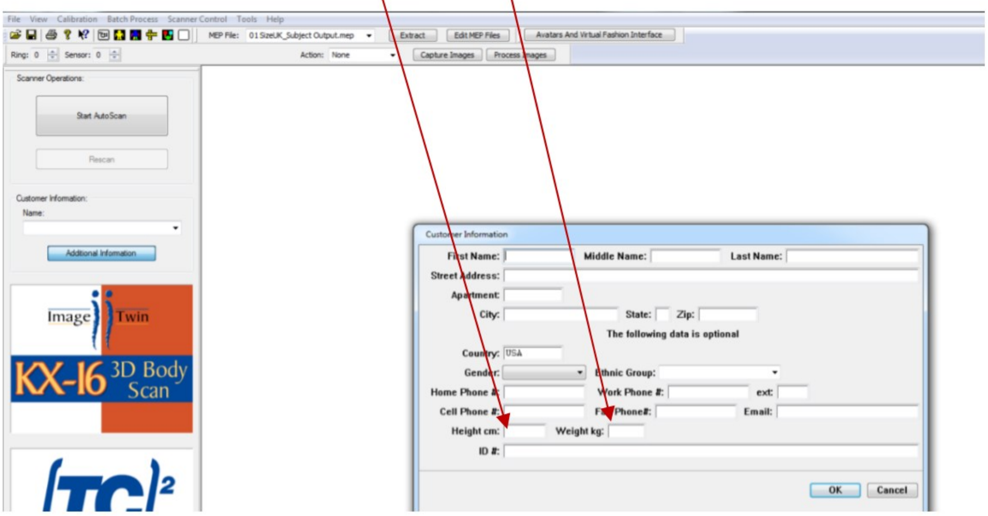
Embedding height and weight

This can be done prior to capturing the scan or may be more appropriate to complete once an accurate scan has been captured.

1. Click the **Additional Information** button under the name field



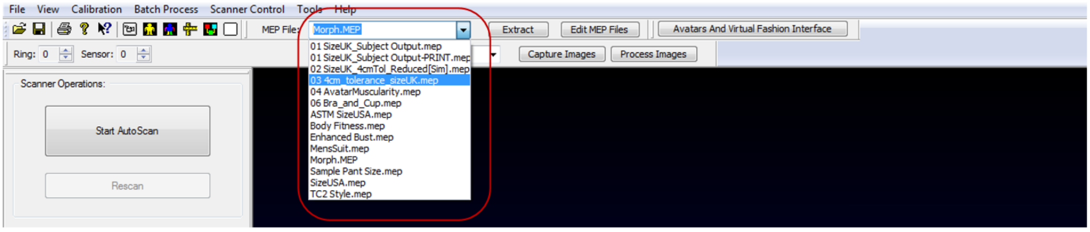
2. Input the participant's **height** and **weight** in the opened window, then click 'Ok'.



Make sure that there is enough space for 5 digits for Height and 5 digits for Weight. If not, customize the CustInfoTemplate.txt file as described in section 9.

Extracting measurements from the scan

3. Select the correct MEP using the drop down menu in the MEP file window of the top tool bar. The correct MEP should be established prior to beginning scanning and will depend on the use of the data. Custom MEP’s can be created for specific uses.



Instructions for scan capture

Ask the participant to adopt the correct posture for scan capture:

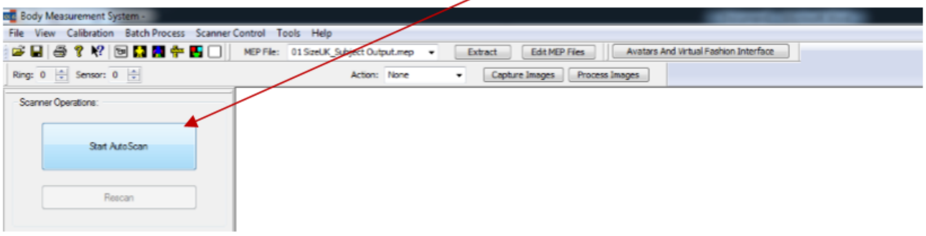
1. Feet placed on the floor markers
2. A natural relaxed posture is adopted
3. Head upright and facing forward
4. Arms with elbows straight and held to the side of body (a handle may be positioned in the scanner to increase stability, one handle will provide up to 90% stability of the upper body.
5. Palms facing thighs and 20-30cm out from the legs

It is helpful to provide visuals showing the scanning position. In addition, a staff member can show the scanning position and make sure the participant understands it before he goes to the scanning cubicle.

When the participant enters the scanning cubicle, ask them to close the curtain, take the gown off and hang it on the hook between the front scanning panels.

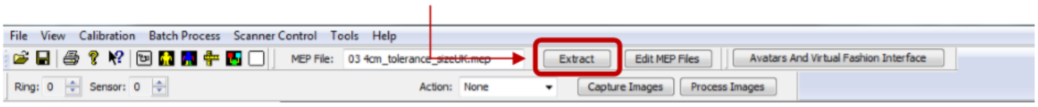
Ask them to indicate when they are ready for scanning (standing in the scanning position and able to hold it for 10 seconds).

4. When the participant is ready click the **Start Auto Scan** button.

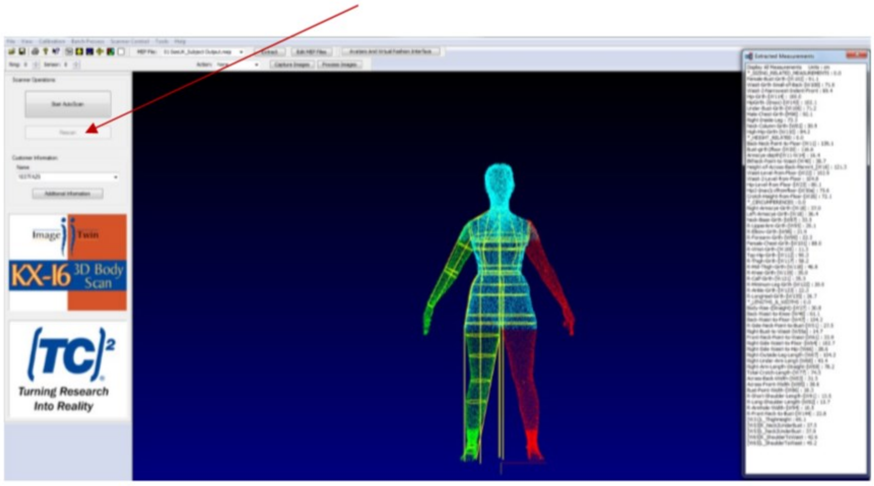


When the scan is captured, click the Extract button on the top tool bar to extract the measurements.

5. When the scan is captured, click the **Extract button** on the top tool bar to extract the measurements.



6. Check the scan to ensure there are no irregularities (the scanning posture is correct; hair is tied; there are no noise occlusions; landmarks are not misplaced). If there are any problems with the scan, ask the participant if they are ok to be rescanned and click **Rescan**. The screenshot below shows a scan with no irregularities.



For evaluating the quality of the scan, you may need to rotate the image or zoom in to it.

When a clear scan is captured, ask the participant to put the gown on and come out. While the participant is changing, print the scan for them (make sure the correct MEP is selected and measurements are extracted).

A printout of the scan should be provided to each scan participant.

24 Appendix P

24.1 SLVM Landmark modifications/amendments notes & codes

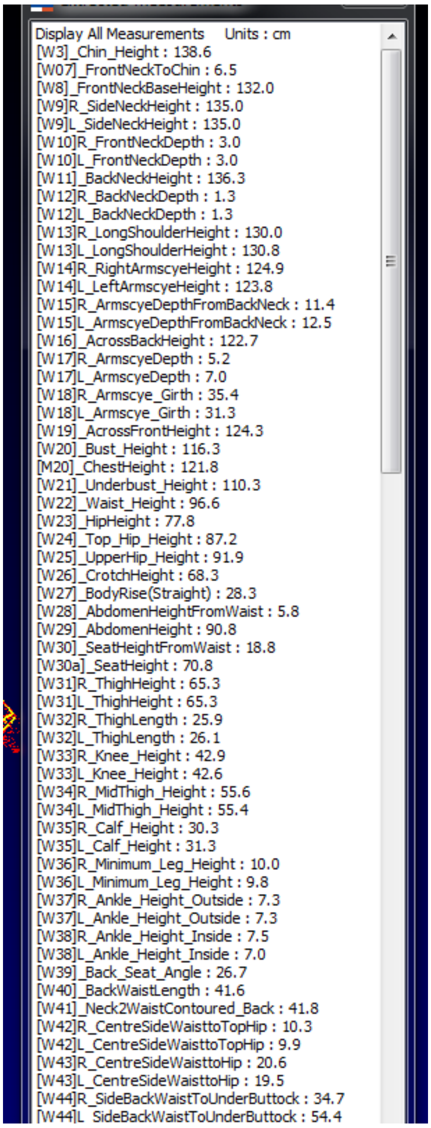
8		Size Nottingham Tuesday					
9							
10	1163FA57_a		57		A - White		
11	1170FA59_a		59		A - White		
12	1172FA55_a		55		A - White		
13	1214FA65		55		A - White		
14	1236FA59		55		A - White		
15	1253FA61		55		A - White		
16	1276FA76_1014AM Jul 02 2013_ptmod-c-a-z	02/07/2013	76	F	A - White	Scan- has known issues that cannot be modified. Modified crotch, armhole points and ankle points.	SG
17	1277FA56_aa_1020AM Jul 02 2013_ptmod-c-	02/07/2013	56	F	A - White	Scan - miscellaneous points have been moved. Crotch point, ankle point and armscye points all modified.	SG
18	1278FA68_1023AM Jul 02 2013_ptmod-c-z	02/07/2013	68	F	A - White	Scan - miscellaneous points have been moved. Crotch point, and armscye points modified.	SG
19	1279FA60_1031AM Jul 02 2013_ptmod-S-Z	02/07/2013	60	F	A - White	Scan - Miscellaneous points have been modified. Armscye, Crotch and Ankle all modified.	SG
20	1281FA60_1035AM Jul 02 2013	02/07/2013	60	F	A - White		
21	1282FA59_1036AM Jul 02 2013	02/07/2013	59	F	A - White		
22	1285FA64_aa_1058AM Jul 02 2013_ptmod-C-	02/07/2013	64	F	A - White		
23	1292FA61_1126AM Jul 02 2013	02/07/2013	61	F	A - White		

Scan with known issues that cannot be modified [X] (This should precede other codes)
Movement of armhole points to correct misplaced armscyes, as shown, [S]
Movement of ankle points, when place to the floor [A]
Movement of crotch point, when mis-division occurs [C]
Movement of Waist levels [W]
Movement of miscellaneous points [Z]

25 Appendix Q

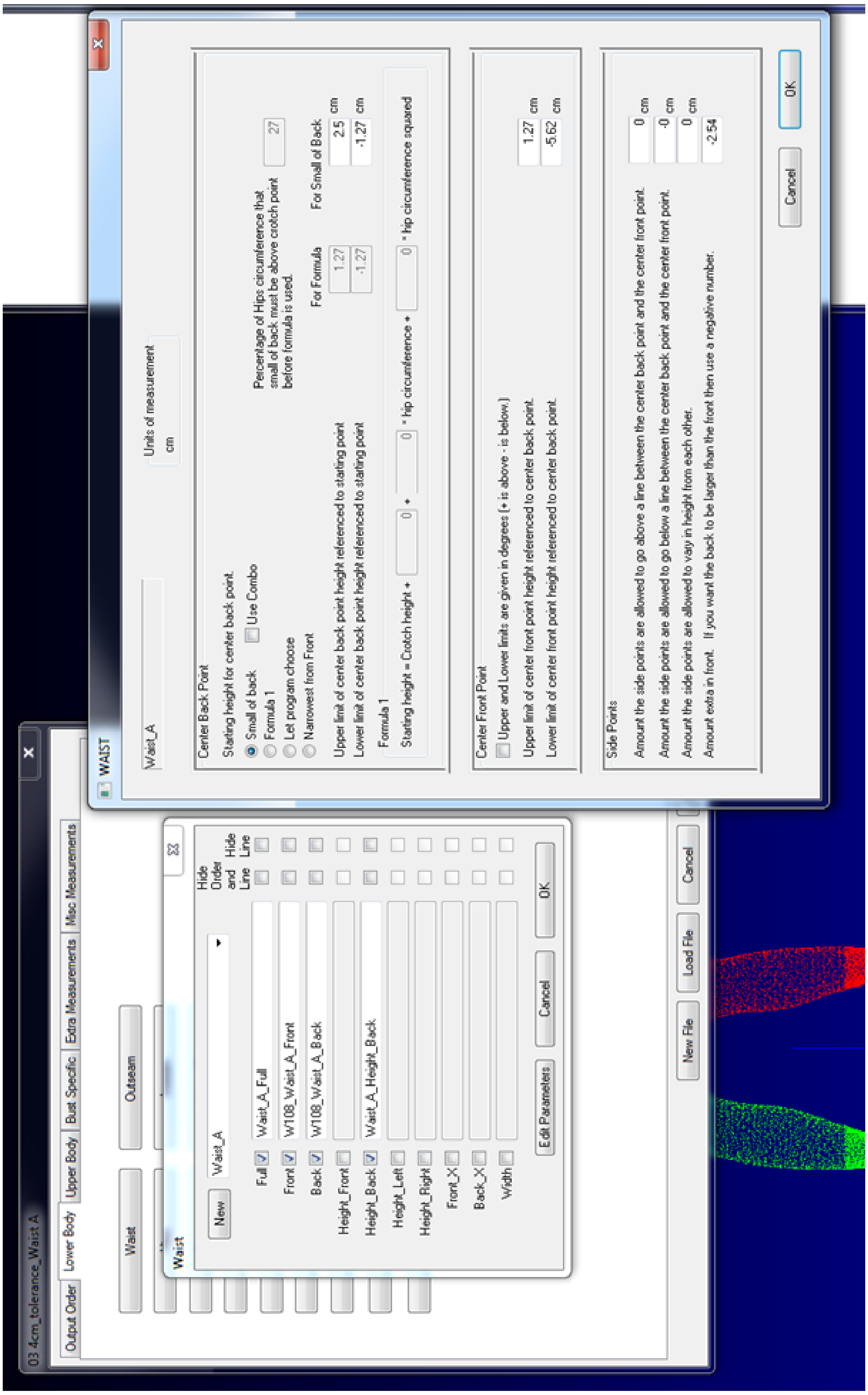
25.1 Example of MEP file definitions

List of measurements taken



Display All Measurements Units : cm
[W3]_Chin_Height : 138.6
[W07]_FrontNeckToChin : 6.5
[W8]_FrontNeckBaseHeight : 132.0
[W9]R_SideNeckHeight : 135.0
[W9]L_SideNeckHeight : 135.0
[W10]R_FrontNeckDepth : 3.0
[W10]L_FrontNeckDepth : 3.0
[W11]_BackNeckHeight : 136.3
[W12]R_BackNeckDepth : 1.3
[W12]L_BackNeckDepth : 1.3
[W13]R_LongShoulderHeight : 130.0
[W13]L_LongShoulderHeight : 130.8
[W14]R_RightArmscyeHeight : 124.9
[W14]L_LeftArmscyeHeight : 123.8
[W15]R_ArmscyeDepthFromBackNeck : 11.4
[W15]L_ArmscyeDepthFromBackNeck : 12.5
[W16]_AcrossBackHeight : 122.7
[W17]R_ArmscyeDepth : 5.2
[W17]L_ArmscyeDepth : 7.0
[W18]R_Armscye_Girth : 35.4
[W18]L_Armscye_Girth : 31.3
[W19]_AcrossFrontHeight : 124.3
[W20]_Bust_Height : 116.3
[M20]_ChestHeight : 121.8
[W21]_Underbust_Height : 110.3
[W22]_Waist_Height : 96.6
[W23]_HipHeight : 77.8
[W24]_Top_Hip_Height : 87.2
[W25]_UpperHip_Height : 91.9
[W26]_CrotchHeight : 68.3
[W27]_BodyRise(Straight) : 28.3
[W28]_AbdomenHeightFromWaist : 5.8
[W29]_AbdomenHeight : 90.8
[W30]_SeatHeightFromWaist : 18.8
[W30a]_SeatHeight : 70.8
[W31]R_ThighHeight : 65.3
[W31]L_ThighHeight : 65.3
[W32]R_ThighLength : 25.9
[W32]L_ThighLength : 26.1
[W33]R_Knee_Height : 42.9
[W33]L_Knee_Height : 42.6
[W34]R_MidThigh_Height : 55.6
[W34]L_MidThigh_Height : 55.4
[W35]R_Calf_Height : 30.3
[W35]L_Calf_Height : 31.3
[W36]R_Minimum_Leg_Height : 10.0
[W36]L_Minimum_Leg_Height : 9.8
[W37]R_Ankle_Height_Outside : 7.3
[W37]L_Ankle_Height_Outside : 7.3
[W38]R_Ankle_Height_Inside : 7.5
[W38]L_Ankle_Height_Inside : 7.0
[W39]_Back_Seat_Angle : 26.7
[W40]_BackWaistLength : 41.6
[W41]_Neck2WaistContoured_Back : 41.8
[W42]R_CentreSideWaisttoTopHip : 10.3
[W42]L_CentreSideWaisttoTopHip : 9.9
[W43]R_CentreSideWaisttoHip : 20.6
[W43]L_CentreSideWaisttoHip : 19.5
[W44]R_SideBackWaistToUnderButtock : 34.7
[W44]L SideBackWaistToUnderButtock : 54.4

Landmark and method of location


03 4cm_tolerance_Waist A
Output Order
Lower Body
Upper Body
Bust Specific
Extra Measurements
Misc Measurements
Waist
Outseam
New
Waist_A
Full
Front
Back
Height_Front
Height_Back
Height_Left
Height_Right
Front_X
Back_X
Width
Waist_A_Full
W108_Waist_A_Front
W108_Waist_A_Back
Waist_A_Height_Back
Hide Order and Line
Hide Line
Edit Parameters
Cancel
OK
New File
Load File
WAIST
Units of measurement
cm
Center Back Point
Starting height for center back point.
Small of back
Use Combo
Formula 1
Let program choose
Narrowest from Front
Percentage of Hips circumference that small of back must be above crotch point before formula is used.
For Formula
For Small of Back
Upper limit of center back point height referenced to starting point
Lower limit of center back point height referenced to starting point
Formula 1
Starting height = Crotch height + 0 + 0 * hip circumference + 0 * hip circumference squared
Center Front Point
Upper and Lower limits are given in degrees (+ is above - is below.)
Upper limit of center front point height referenced to center back point.
Lower limit of center front point height referenced to center back point.
Side Points
Amount the side points are allowed to go above a line between the center back point and the center front point.
Amount the side points are allowed to go below a line between the center back point and the center front point.
Amount the side points are allowed to vary in height from each other.
Amount extra in front. If you want the back to be larger than the front then use a negative number.
Cancel
OK

26 Appendix R

26.1 CDVELA Excel sheet notes

26.1.1 The 55+ age cluster

1	Comparison of demographics and variables which can effect landmarking accuracy (CDVELA)								
2	Code	Body shape	BMI	Age	Ethnicity	Notes	nitial	area of modifications	amount
3									
4		rectangle	23.1	61	A - White	Scan- modified armpit right and left, left and right shoulder point. Subject has back fat deposits near armpit and around bra. Lower right shoulder than left.	PW	armscye	1
5		rectangle	28.7	61	A - White	Scan - modified back left armpit, top armhole R, soft shoulder R and shoulder point R. Occlusions on wrists which are patched.	PW	armscye	1
6		rectangle	28	55	A - White	Scan- modified right shoulder point,armhole top front armpit. Modified left shoulder point, armhole top point. Noise around chin, chin point is off centre of chin. Waist high	PW	armscye, chin, waist	2
7		triangle	41.4	59	A - White	Scan- Issues with right side of scan. Occlusion on right breast which is patched. Modified R and left front armpit, shoulder point, top armhole, back armpit. Occlusion under right arm. Occlusion at C7. Noise on shoulders. Occlusion on right wrist which is patched. Data missing on right foot. Waist is placed near underbust. Hip girth is high due to large hanging skin folds and fat deposits on abdomen area. Occlusions under abdomen folds near low hip point.	PW	armscye, waist lots of issues	2 including waist high
8		triangle	37.3	65	A - White	Scan - Missing data on right foot, W137R & W138R not handled. Modified Left & Right shoulder points and armhole tops. Modified right soft shoulder point. Waist is too high and is placed near underbust, needs new definition.	PW	ankles, armscye, waist,	3 including waist high
9		bottom hourglass	25	55	A - White	Scan - occlusions around the left long/soft shoulder area. Moved soft/long shoulder landmark to more match right position. Left armscye hight LM has overlapping data and the landmark is 2cm higher than the right this has been moved down. Left armpit LM has moved to the back this has now been modified.Data missing on right foot although ankle point is ok. Waist is placed at under bust although this is the narrowest point on the torso. Moved waist down so it has increased by 2cm.	PW	armscye, waist	2 including waist high
10		rectangle	34.9	65	A - White	Scan - occlusions around left armpit. R armscye bigger than left as right point is place more on the chest. R & L armpit LMs modified. Shoulder, soft shoulder and top armhole points modified on right. Subject displays asymetrical shoulder angles	PW	armscye,	1
11		rectangle	31.1	62	A - White	Scan - left armpit front and back are too far over so have been modified. Waist appears high. Waist LM small of back moved down slightly.	PW	armscye, waist	2 including waist high

12	rectangle	30.2	63	A - White	Scan-W137 & W138 not handled as missing data. R crown hight measurement looped around hair although soft should is positioned correctly. The head however is leaning to the right which could have effected this measurement. Left armpit looks too far onto body but when viewed in grey surface it is correct. The shoulders are quite rolled forward and the spine is curved. Under bust girth is not sitting under the right breast and the measurement is mainly sitting on the abdomen. Waist is sitting directly on top of the under bust girth, modified.	PW	armscye, waist	2 including waist high	
13	rectangle	25.9	71	A - White	Scan- the X front and back chest measurment is slightly angled but the subject is slightly swaying to one side therefore the shoulders are lower on one side than the other. Spine posture is very upright with little curvature around the shoulders. The subject is leaning towards the anterior position when viewed from the side. Scan does not need modification.	PW	n/a		
14	rectangle	21.4	56	A - White	Scan - issues with neck column and neck base girth measurements. There is a lot of noise around the neck perhaps from subject movement or the scanner picking up hair which has resulted in a very thick neck visually and large circumference measurements. L side neck landmark is modified to give a smaller neck base girth measurement.	PW	neck	1	
15	rectangle	26	79	A - White	Scan - subject displays extreme bilateral asymmetry. chin point modified. R armscye girt is looped around the chin LM (R armhole top, soft shoulder, shoulder, back and front armpits all checked but measurement still looping). Righ crown height is extended into the head despite LM's being correct. There is a lot of data missing from the head and neck region so the neck base and neck column girth is unreliable. Shoulder lengths are vastly different with the left shoulder being 16.7cm longer than the 3.5cm right one. R elbow LM is very high on the right arm, this has been modified. This moved the forearm measurment down the arm. Waist and underbust measurements are lying directly on top of each other. The subject displays additional conturing along the spine (around the small of the back)perhaps as a result of the underwear she is wearing. Waist modified. This has made the waist placement high. W135 not handled.	PW	chin, armscye, elbow, waist,	4 including waist high	
16	bottom hourglass	30.1	63	A - White	Scan - chin LM is modified. Data missing from back of head and neck with the 7th C just allowed to be marked in. Noise around shoulder, data missing on right breast. Occlusions around both armpits. R armscye depth is smaller in measurment because there are more occlusions. When the R armpit landmarks are moved the measurement is some times out as the landmark moves into an occlusion and thus not read my the software. Right armscye is shaped as flat around the should point when it should be a curve. RW65 shoulder to waist's measurement is penatrating in and out of the point cloud giving a large measurement value of 165.2 when compare to 45.7 for the left measurement. Cannot modified this measurement because it is caused by occlusion. Waist is high, near the underbust, this has been modified.	PW	chin, armscye, waist,	3 including waist high	
17	rectangle	29.1	70	A - White	Scan - chin pointo modified as it was placed slightly to the left. R arm pit point placed on breast and not at underarm - modified but difficult as occluded under armpit. Waist seems a little high - modified moved down by a few mm. Used left shoulder (W91L) and left armhole width (W94L) measures for raw scan data pattern development as the right was too short. Moved right front armpit as too far on bust.	PW	chin, armscye, waist	3 including waist high	

18	rectangle	28.1	68	A - White	Scan- W37 not handled. Large occlusions at the back of the head and neck. C7 LM has been placed but unsure of accuracy. Noise around the left shoulder and armpit. Back armpit points seem angled but subject is leaning towards the right. Modified left armhole, front and back armpit points.	PW	armscye	1
19	rectangle	21.8	55	G - Any oth	Scan - subject is slim. Back of head is completely missing although the neck is there for the C7.Neck base girth and neck column lie on top of the C7 LM where as these measures normally lie above. Noise around front armpits and front armpit LMs cannot be seen on grey surface model but armscye measures seem fine. Bust waist and hips seem fine no modification to the scan.	PW	n/a	
20	rectangle	24.7	80	A - White	Scan - subject displays slight bilateral asymmetry as body leans to the right. Scanned twice as neck column girth not handled. Lots of noise and occlusions around both armpits with R & L armscye girth measurements being very small. Top of arms have fatty/flabby areas which could have caused shadowing. Back front and top armscye LM L&R all modified. Chin moved as off centre to right. R bust point not on prominence of right bust - modified. Underbust measure is taken straight and really should be slightly pitched as subject is leaning to one side. Need to use under bust parameters in edit points to chage how the scanner takes the measurement. Waist girth lies directly on small of back.	PW	armscye, chin, bust,	3
21	rectangle	24.9	58	.	Scan - subject shoulder points need modification left too high right too low with a difference of approx 10cm in the measurements - these have been modified. Small of the back is rather low but this cannot be automatically altered in edit parameters. Bust points are not on the most prominent part of the bust - modified.	PW	armscye, bust	2
22	triangle	27.5	69	A - White	Scan - hair data missing though not effected C7. Slight occlusion under right armpit though this has not impacted on the measurement. Wrist LM modified (moved up the arm).	PW	wrist	1
23	rectangle	25	60	A - White	Scan- Slight occlusion under right armpit. Noise around shoulders and armpits. Right armscye girth seems a little high on the shoulder - modified. Right shoulder is more square and muscular than the left hence large armscye measurement. Waist girth is mm away from the underbust measurement - waist modified and moved downward passed the small of the back LM. Small of back high as subjects posture is leaning toward the anterior plane.	PW	armscye, waist,	2 including waist high
24	rectangle	21.6	57	A - White	Scan - entire top of head and some of the back neck missing. Scanned twice as first scan had loads of errors. Error with Right armhole point,very high on the shoulder - modified. Right front armpit LM moved as lying on the chest. Left armhole point moved upward as lying on arm. Noise around the neck with neck base girth appearing a small and angled measurement. Subject is pushing hips forward and has a 'sway back' posture. This has made the scanner place the waist very low beneath the navel and very near the top hip. Small of the back is placed very near buttocks and back waist LM lies directly on top of this. Waist and small of back LM modified.	PW	armscye, waist, small of back	3 including waist
25	rectangle	26.3	66	A - White	Scan- Looks like hair could be lying on the neck making the measurment large for the Neck column and neck base girth. Lots of noise around the right armpit area making image look like it is peaking on the arm. Left front armhole modified as the LM was hidden under the armpit.	PW	armscye, waist	1
26	rectangle	23.5	65	A - White	Scan - Armpits modified both left and right. Armhole top R&L LM modified. Waist girth too high very near underbust measurement. Waist back LM moved downward.		armscye, waist	2 including waist

27	top hourglass	33.2	73	A - White	Scan - occlusions around the bust and right armpit region. This has impacted on the right arm measurments. It appears the subjects bra strap fell down on the right side and this has caused issues for the entire arm and some of the bust measures. R armscye depth LMs have been modified. Will have to use left arm girth and length measures. Bust girth is large and appears to be encompassing part of the right arm. Underbust girth has been misplaced and is lying too close to bust girth. Underbust girth LM have been modified and moved downwards. R ankle height not handled. Not a great scan unsure if could make a pattern from this.	PW	armscye, underbust, ankle	3 inclusing waist	
28	triangle	24.2	62	A - White	Scan- Centre back neck point is slightly toward the right of the body, modified to be more central. Neck base girth is lying under the C& point - unusual. Both armpit front and back are incorrect due to how the different views have been overlayed, modified. Armscye girth measurements are improved. Left forarm girth is too high, sitting almost on the bicep, olecranon modified. No wrist measurement for the left hand.	PW	CB neck, armscye, forearm girth, elbow	4	
29	rectangle	18.8	69	A - White	No issues	PW			
30	bottom hourglass	25.7	63	A - White	Scan - Chin point modified. Right front armpit LM not visable on grey surface view though the armscyes look fine.	PW	chin, armscye	2	
31	rectangle	31.5	68	A - White	Scan - Left armhole top LM is higher on the shoulder - modified. Left front armscye is too far onto chest - modified. 6cm difference between left and right armscyes though they look ok. Left upper arm girth is 4cm different to the right one, the measure looks flat on the inside of the arm - due to missing data? Right wrist girth looks large - modified. Waist slightly high - modified.	PW	armscye, wrist, waist	3 including waist high	
32	rectangle	21.9	58	A - White	Scan - no issues		n/a		
33	rectangle	22.6	57	A - White	Scan - Neck girth (column and base) are large due to hair on shoulders. Bust girth measurment is not over point of greatest protrusion on the left breast - modified. R Wrist small - missing data? Data missing on left foot.	PW	bust	1	
34	rectangle	18.9	71	A - White	Scan - Taken on the KX scanner. Right front armpit is too far onto chest - modified. Right back armpit modified. Right bust point is not at point of greatest protrusion - modifed. Waist girth slightly high - modified. Data missing at crotch point on left thigh, use right thigh measures.	PW	armscye, bust, waist	3 including waist high	
35	triangle	20.4	57	A - White	Scan - The resolution is not good and the scan is very rough with lots of surface 'peaking' around the shoulder area. Subject dose not look as though she is wearing a bra. Left armscye incorrect, front armput too high on chest and the shoulder point is very near snp - all modified. Subject displays assymentry of posture in the torso region viewed front on. Subject is slim.	PW	armscye	1	1
36	rectangle	38.3	60	A - White	Scan-subject is wearing a swimming costume which has caused creasing around the back waist region.	PW	n/a		
37	rectangle	26.4	61	A - White	Scan - subject has one leg (R) slightly longer than the other making them slightly tilted to the left. Crotch point is too high - modified. Modifying this has thrown 38 R ankle to floor outside points out and they will need modifying.Crotch still looks slightly off centre but cannot be modified to the side. Subject has very rounded cervical region of spine. Waist too high - modified.	PW	cotch,ankle,waist	3 including waist	3
38			68	A - White	Scan- This scan has too many issues to be accurate.	PW	n/a		
39	rectangle	26.4	70	A - White	Scan - Subject is slim. Subject displays asymmetry and the hips are more rounded on the left of the body. The head position is held very high with the chin jutting out. Lumber portion of the spine is flat. The cervical portion of the spine is curved around the neck. The small of the back is visually apparent but the curve is shallow. Errors with shoulder measurements which has made the measure wrap over the ears. Left armscye has several errors due to noise and movement. This can cannot be modified.	PW	armscye, waist	1	1

40	rectangle	28.1	64	A - White	Scan- waist looks a little low and is very near the top hip - back waist LM moved slightly upwards. There appears to be indentations near the waist/top hip region. This is from lingerie. Crotch too high - modified. Modified left elbow and olecranon LMs.	PW	waist, crotch, elbow	3 including wa	3
41	hourglass	30.5	61	A - White	Scan- crotch point too high - modified. The subject has curves at the side of the body to indicate a waist. Under bust and waist measurements are sitting on top of each other - moving waist downward slightly. Moving the waist appears to throw the ankle height measurement out will modify. Subject carries adipose fat in the abdomen which makes the abdomen protrude when viewed side on.	PW	crotch, ankle, waist	3 including wa	3
42	rectangle	20.9	55	A - White	Scan - subject has slight curvature around the cervical portion of the spine. Small of back curve is very shallow, thoracic spine is flat as is the buttocks. Occlusion around right armscye at the back making the measure 7cm larger than left. Cannot be modified go with left measurement. Waist appears slightly high - modified. Left olecranon too high moved down to elbow region.	PW	waist, elbow	2 including wa	2
43	rectangle	25.9	62	A - White	Scan - R armscye girth too big - modified. Waist very near under bust girth - waist moved approx. 1cm passed small of back LM. Crotch point too high moved down slightly.	PW	armscye, waist, crotch	3 including wa	3
44	rectangle	25.9	65	A - White	Scan - left shoulder point has been moved up the arm slightly. Use left armscye more reliable.	PW	armscye	1	1
45	rectangle	23.6	63	A - White	Scan -R shoulder point is a little low - modified further up the arm toward the true shoulder point. Front R armscye LM modified, too far over on the body. Waist is slightly high moved down from centre back waist LM. Crotch too high - modified.	PW	armscye, waist, crotch	3 including wa	3
46	rectangle	26.1	65	A - White	Scan - r and l armscyes incorrect, modified. Neck base and neck column girth are very close together. Waist is too high, modified. Crotch point is too high - modified. Olecranon moved down on right arm to correct upper arm girth measure.	PW	armscye, waist, crotch, elbow	4 including wa	4
47	rectangle	27.3	69	A - White	Scan- peaking around R elbow though measure is ok. Crotch slightly high - modified.	PW	crotch	1	1
48	rectangle	26.4	63	A - White	Scan - Crotch too high - modified. Subject displays a fat roll around the torso region which may be the result of elastic on pants. The waist measure is sitting on top of this indentation and on the small of back LM. Waist looks fine so no modification. Both R & L armscyes are incorrect - modified both front armpits, shoulder points and back armpits. Occlusions around R back armpit making modification difficult. Peaking and noise around both L&R elbows - measures unreliable.	PW	crotch, armscye, waist	2	2
49	rectangle	25.2	64	A - White	Scan - Subject displays a pear shape. L armpit front is place slightly on the arm - modified. Subject has a slightly flat lumber region on spine. Waist very slight too high moved down. Crotch too high - modified.	PW	armscye, waist, crotch	3 including wa	3
50	rectangle	24.4	68	A - White	Scan - subject has slim arms and legs. Posture is leaning forward, chin is down and there is a curve around the cervical and lumber portions of the spine. Subject is slightly leaning to the left when viewed front on. R armscye girth is incorrect - modified starting with armhole top LM. Front R armpit LM modified as placed on arm. Quite a lot of asymmetry around the top torso when viewed carefully. Waist girth sitting on top of under bust girth. waist moved down slightly beyond small of back LM. This person possibly wears their waistbands pitched. Crotch too high - modified. Thighs are touching.	PW	armscye, waist, crotch	3 including wa	3
51	bottom hourglass	24.8	68	A - White	Scan - This scan has issues. The left arm is touching the body making the left side for arm measures unreliable.	PW	use right arms		
52	rectangle	24	64	A - White	Scan - outside foot (38) not handled. Subject shows swayback posture. Curve at small of back is distinct. Noisy on top of right and left shoulder just at change of angle. Waist appears too high - modified. Crotch too high - modified. 114 largest hip measure is sitting in an indentation possibly caused by lingerie, not sure if I should modify.	PW	ankle, waist, crotch	3 including wa	3

	Code	body shape	BMI	age	ethnicity	comments	Initial	modifications		
53		rectangle	21.9	58	A - White	Scan - subject has upright posture and small of the back curve is visually clear. Both armscyes are too small and need modification. There are occlusions around both armscyes and there is also some peaking of the surface at the underarm near the armpit. Armhole tops on both R&L are also too high on the shoulders - modified. Arms are held a little too far from the body and this has raised the shoulders slightly. Subject is wearing spanx pants which extend to the knee region. Crotch point does not need altering is this due to the spanx which has given a distinct thigh gap? Subject is also wearing a strapless bra. Waist too high - modified. R calf girth too high - modified both knee girth LMs to correct.	PW	armscye, waist, calf girth, knee	4 including wa	4
54		rectangle	29	67	A - White	Scan - subject has part of the inner left thigh missing so use right leg for accurate measures. Left armscye girth look incorrect. The Left top armhole point is sitting too low on the arm if compared to the right. Subject does not display extreme asymmetry. Modified top left armhole LM. Elbow LM appear too low on the arm - modified. Left wrist too low - modified. Crotch appears high and not centred to the body but data is missing from left inside leg - modified. Waist too high - modified. Left thigh girth is unreliable, use right.	PW	armscye, elbow,wrist,crotch, waist,	5 including wa	5
55		rectangle	28.9	83	A - White	Scan - subject has arms held far from the body. There is extra data in the scan perhaps from an improperly closed curtain? Left armscye girth measure looks too low on the arm and the extra data is attaching itself to the left shoulder, top left armhole modified. Left wrist measure is too high and data is missing lower down at true wrist point. The measure is unreliable use right. Subject is wearing a vest which has smoothed over the torso. Under bust point is difficult to see. Waist is place on top of the under bust and looks too high - modified. Crotch has data missing on the left leg making the left thigh girth unreliable. The crotch point is too high.	PW	armscye, wrist, waist, crotch	4 including wa	4

26.1.2 The 35-45 age cluster

1	**Comparison of demographics and variables which can effect landmarking accuracy (CDVELA)**							
2		35-45 body sca	38 scans	32 useable				
3	**Code**	**body shape**	**age**	**BMI**	**ethnicity**		**Initial**	**modifications**
4			37		A-White	Scan - not in TC2 system	PW	
5		rectangle	39	27.2	P-Black	Scan - subject has a large distended abdomen and I round protrucding bottom. R armscye is incorrect - lying on the breast region - modified. Lots of noise and occlusions around the shoulders and armscyes. Neck base and column nearly touch. Thighs touching though crotch point has been modofoed at scan. L wrist unreliable. Bust point looks low but at the bust prominence. Waist and upper hip too high - modified.	PW	armscye,crotch, waist, upper hip
6			35		P-Black	Scan - 38 outside R&L not handled. 69, 69b, 69c not handled, 96 not handled, 100 R not handled, 123 L and 135 R not handled. ankle points not modified as data missing. Subject has excess adipose fat and has a large protruding abdomen and a high rounded buttocks. Neck base and column almost touching. No LM for R elbow so could not modify. Use lef elbow for measures. Min leg girth not reliable. Scan has issues with missing data.	PW	
7		bottom hourglass	37	23.4	A-White	Scan - subject is slim. No issues	PW	
8		triangle	39	26.5	A-White	Scan - subject has bend arms so elbow and wrist are mis-aligned - modified. Arme length cannot be trusted. The scan has many issues so cannot be trusted. Subject is wearing a vest so shoulder points are too low on arm - modified.	PW	elbow, wrist, shoulder
9		rectangle	40	29.1	A-White	Scan - L ankle inside to floor (38) not handled - modified. Subject is wearing a vest. Arm circ may be increased because subject is part-clothed, particulalrly wrists. Should points both right and left too low similar to 0279FA39. Buttocks and lumber spine appear flat viewed side on - could be vest disguising the curve on small of back. Cervical and thoracic spine has defined curve.	PW	ankle
10		rectangle	36	22.9	A-White	Scan - subject appears to be rectangle shape viewed front on. Subject has a slight protruding abdomen. Curve of back is very shallow. Neck base and column not touching. R elbow LM too high - modified. Waist is a little too high - modified.	PW	elbow, waist
11		rectangle	38	21.7	A-White	Scan - subject is slim but has a slightly protruding abdomen. R ankle outside to floor not handled - modified. Subject displays upright posture arms are parallel to the sides.	PW	ankle
12		rectangle	40	26.6	L-Asian	Scan - subject displays a large protruding abdomen. It appears that the bra is creating indentations on the back just above the small of the back. Subjects hair is down but there is a visible C7 LM. Data missing on the neck meaning neck column girth maybe unreliable. Neck column and base are touching. Breast point is low but is at the prominence. Waist allmost touching the under bust measure - modified at waist back.	PW	waist
13		rectangle	36	33	P-Black	Scan - L armscye incorrect as back LM is lying on the back and not at crease of armpit- modified. Subject has excess fat around the armpits. Subject carries fat around the abdomen. Data missing/hair around the neck measures unreliable. Neck column girth is spread across the chest and neck base is wrapped twice around the front of the neck. Thighs touching but LM look ok. Bust looks firm.	PW	armscye

14	hourglass	42	18.4		Scan - subject is very slim. Neck base and column girths are touching at back LM. Subject has sway back. Both back armpit LM are too high - modified.	PW	armscye
15	rectangle	37	30.9	A-White	Scan - subject's waist is not clearly defined. Subject has small curve at small of the back but their posture is upright with shoulders relaxed. Arms parallel to the side of the body. R armscye is incorrect too far onto the chest at the front - modified. Armhole top L&R are too high on shoulder - modified. patching at the L armpit which has made the front armpit too far on chest - modified. Neck base ans column not touching. Bust girth is slicing through the torso as there is a lot of occlusion & patching at the armpit points. Subject has excess fat around the torso and the top of the arms.	PW	armscye, shoulder,
16	rectangle	41	25	A-White	Scan - Neck base and column girths not touching. Subject displays a low small of the back curve and despite having a natural indentation at where one would expect the waist to be the scanner has placed the waist lower on the torso.	PW	n/a
17	rectangle	37	24.3	A-White	Scan - Subject has a small protruding abdomen, slight indentation at the waist region and maintains an upright posture. Cervical and thoracic regions of the spine are gently curved. There is a shallow curve for the small of back down towrds the buttocks. neck base and column are touching. Waist appears high - modified.	PW	waist
18		42		R - Chinese	Scan not in system	PW	
19	rectangle	35	24.1	A-White	Scan - Ankle to outside floor R (38) not handled - modified. R armscye at back incorrect as too far on torso and too low. L back armpit also modified as too far on body. Lots of patching around the armpit region. The subject displays body fat at armpits, the scan has occlusions and has attempted to patch where possible. Crotch too high, modified. Neck column and base girths are touching. Subject has slight curve at cervical portion of spine. R upper arm girth has data missing use L. Waist slightly high - modified.	PW	ankle, crotch, waist, armscye
20	hourglass	42	25.5	A-White	Scan - Ankle outside to floor R not handled - modified. Back R armpit LM modified as too low. Subject has a protruding abdomen. Posture is upright. Neck base and column girths touching. L wrist unreliable as data missing. Large bust whose bust point sits low on the torso. Waist and underbust measures are close but the position of both look ok.	PW	n/a
21	hourglass	35	23.2	A-White	Scan - no issues	PW	
22	rectangle	40	18.3	A-White	Scan - L & R front armpit points modified.	PW	armscye
23	rectangle	36	21.4	A-White	Scan - R elbow too high - modified. Shoulder length too small, modified. Arm scye depth is much too small but cannot modify using modifiy point facility.	PW	elbow, shoulder
24	hourglass	37	21	A-White	Scan - L shoulder too low on arm - modified.	PW	shoulder
25	bottom hourglass	43	30.1	G - Any other Mixed background	Scan - subject is very curvy and has a very deep curve at the small of the back due to a large rounded buttocks. right ankle to floor not handled, does not allow it to be changed in modifiy point (use mep v5 SG). Neck column and neck base girths touching. Subject looking upward so chin point is incorrect - modified. R elbow girth LM incorrect - modified. Thighs are touching modified crotch point. Waist near underbust modified. Ankle girth on left is unreliable, use right. There is data missing around the x chest, x back and armhole width measures - shading. This has introduced error in the measure which cannot be resolved with the cleansing process. Shoulders L & R have been extended and modified	PW	chin, crotch, waist,
26	rectangle	45	33.8	G-Other	Scan - subject carries a large amount of fat on the abdomen. Knees are hyper extended. L & R armpits LM modified as too far on torso. Neck column and base girths are touching. R elbow too high - modified. Waist slightly high - modified.	PW	armscye, elbow, waist, shoulders
27	rectangle	41	22.5	A-White	No issues	PW	
28	rectangle	43	23.9	A-White	Scan - R armpit and soft/shoulder point modified.	PW	armscye, shoulder
29	rectangle	42	28.2	P-Black	Scan - ankle to floor outside right not handled, cannot be modified. Both armscyes are incorrect - modified. Use left armscye mesures as too many issues involving occlusions on the right. Subject is wearing a poorly fitting bra and has lots of spillage on the right breast. Neck column and base girths are touching. R bust point modified.	PW	armscye, bust
30	hourglass	38	23.6	A-White	Scan - subject has slight sway back posture. Crotch point moved.	PW	crotch

	Code	Shape	Age	BMI	Ethnicity	Notes		Landmarks
31		rectangle	38	34.4	A-White	Scan - slight noise on shoulders. Armscyes modified. Crotch modified. Wasit directly on top of underbust - modified.		armscye, waist, crotch
32		bottom hourglass	45	26.6	A-White	Scan - modified ankle, crotch and armscye LM. Neck column and neck base touching.	PW	ankle, crotch, armscye
33		rectangle	41	22.7	A-White	Scan - scan clear, no issues with the measurements	PW	n/a
34		rectangle	46	41.7	A-White	Scan - subject has a distended abdomen and a very deep curve at the small of the back. There is shadowing under the abdomen and this has meant occulded areas around the crotch point. The crotch is too high - amended. Thighs are touching. Elbow on the left arm is too high - amended. The left arm is slightly touching the body which has distorted the point ckoud slightly. The arms carry fat and this has impacted on the posture of the arms.	PW	crotch, elbow
35		rectangle	46	42.5	A-White	Scan- subject has a distended abdomen and is carrying fat deposites around the torso particulalry on the back. Left armscye points need adjustment - modified. All other measures are ok.	PW	armscye
36		bottom hourglass	37	19.5	A-White	Scan - subject is slim. Posture is kyphotic and subject is leaning forward slightly. Right armscye points are modified and right shoulder front is too far on the body and the should point is too high. Shoulder point is amended.	PW	armscye, shoulder
37			35		A-White	Scan - too many issues with scan	PW	
39		rectangle	45	24.4	A-White	Scan - Crotch point too high - modified.	PW	Crotch
40		triangle	45	22.9	A-White	Scan - Chin mislocated - modified. R elbow too high - modified.	PW	chin, elbow
41					A-White	Scan - crotch too high missing part of leg. Both elbow too high modified. Arms are held close to the body causing 'peaking' on the skin surface. Waist too low, very near upper hip, on top of small of back and near top of buttocks - modified at waist back LM. This subject has a large fat deposit around the abdomen which extends to the back and sides of the body. It is this shaping which could have impacted on waist LM placement. There is too mucjh peaking on the torso for the measures to be reliable	PW	

26.1.3 <u>The 18-25 age cluster</u>

1	**Comparison of demographics and variables which can effect landmarking accuracy (CDVELA)**									
2				18-25 body scans for PhD - sample size 66			arms cye	crotch	waist	knee
3	**Code**	**age**	**Shape**	BMI	**21**		**17**	**3**	**0**	3
4		21	rectangle	27.2	A-white	L outside ankle point go with right. Crotch modified	PW/S	crotch	1	crotch
5		21	bottom hourglass	22.8	A white	Scan - Waist is fine, lying on navel	pw	n/a		
6		19	top hourglass	26.9	not stated	Scan - both L&R armscye girths look small - modified all landmarks front, top and back on both arms. Crotch too high - lowered between legs slightly. Neck column and base do not overlap. Underwear casuing skin drepression around the hips.		armscye, crotch,	2	
7		20	bottom hourglass	20.2	not stated	R inside ankle use left	PW	n/a		
8		20	bottom hourglass	24.8	P Black	Scan - subject is slim. Both R & L armscye girths are incorrect with the R being particularly out (back LM lying on the arm, front on the chest) - modified back top and front LMs on both. Shoulders are assymentrical. Crotch slightly too high lots of patching around the area. Neck column and base do not touch except at C7. Bust points are not at nipple and sit on the top edge of the bra, the bra is depressing the breast prominence causing spillage - modified.	pw	armscye, crotch, bust	3	

9	25	hourglass	19.6	A-white	noise around chin. Neck measures	PW	n/a		
10	20	rectangle	21.8	P - Black	Scan - Left wrist data missing, girth is small, data missing on left foot no foot width or foot girth measurments	PW	n/a		
11	19	rectangle	19.4	A - White	Scan - moved left top shoulder poi	PW	armscye	1	
12	21	rectangle	21.4	R - Chines	Scan -shoulders are square, moved	PW	armscye	1	
13	22	hourglass	22.3	A - White	Scan- modified left armpit point	PW	armscye	1	
14	20	top hourglass	20.4	A - White	Scan - occlusions around top of both shoulders, top shoulder and shoulder points modified. Left elbow point modified. Occlusion on face scanner has patched a profile for chin LM.	PW	armscye, elbow,	2	6 arm
15	21	hourglass	20.3	A - White	Scan - back right arm pit point mo	PW	armscye	1	
16	20	triangle	20.4	A - White	Scan - subject is wearing incorrect underwear. W44L measurement is penetrating the point cloud and is far greater than the right side making the measurment unreliable. Use W44R.	PW	n/a		
17	19	rectangle	18.4	A - White	Scan - subject has square angled shoulders. Both shoulder points need amendment as too high on shoulders, both front armpit points have been modified, back left armpit has been modified.	PW	armscye,	1	
18	20	bottom hourglass	21.3	A - White	Scan - occlusions around crotch point which as already been modified. W42L & W43L not handled. Both shoulder points and armpit points on the front plus the left back arm pit have been modified.	PW	crotch, armscye	2	
19	20	bottom hourglass	32.3	A - White	Scan- R shoulder point is a little low on the arm - modified. Crotch point too high. The thighs are touching with the left thigh being 2cm larger than the right. Neck column girth is unreliable as part of neck is missing.	PW	armscye, crotch	2	10 as
20	19	hourglass	14.4	A-white	Scan - subject is slim. Neck column and base do not touch. No issues with the scan.	PW	n/a		
21	23	rectangle	23.5	A- white	Scan - Surface of the breast is rough and pixcellaed in grey view. LM looks like it is not placed on the most prominent part of breast. However the LM are sitting on or around the nipple point.	PW	n/a		
22	23	hourglass	25	A-white	Scan - subject has well defined waist. No issues	PW	n/a		
23	20	rectangle	19.9	A-white	Scan - subject is slim. R shoulder is slightly lower than left. Data missing from the tips of the breasts. L wrist unreliable too small a measure. Waist sits below natural indentation. No issues	PW	n/a		

	A	B	C	D	E	F	G	H	I	J
24		22	rectangle	20.6	A-white	Scan - R ankle outside floor left no handled modified. Subject has a definable waist but between upper hip and lower hip the body shape is very rectangular. Subject has a slight bulge at abdomen and bust point is sagging. Waist slightly high - modified so it sits within the natural indentation at the sides.	PW	ankle, waist,	2 including waist	
25		20	top hourglass	16.6	A-white	Scan - subject is slim. Crotch point looks very slightly high - modified. Bust points are high but look placed on the prominence of the breast.	PW	crotch,	1	
26		20	hourglass	19.3	A-white	Scan - Crotch is a little too high - modified. Neck column and neck base girth do not touch. L wrist unreliable use right for patterns.	PW	crotch	1	
27		20	rectangle	17.9	L - Asian	Scan - R ankle outside not handled -modified. Arms are very bent and the wrists are unreliable. Top of head is missing and chin appears near noes as face is missing this cannot be modified. Head looks like it is jutting forward. Crotch look slightly high - modified although occlusions around the crotch. Subject has clearly definable waist. Neck and neck base girth do not touch.	PW	ankle, crotch,	2	
28		25	hourglass	19.6	A-white	aprat from front neck to chin there	PW	n/a		
29		24	rectangle	19.9	P-black	no bra. Armsheld wide. No issues	PW	n/a		
30		19	rectangle	21.4	A-white	Scan - R outside ankle not handled - modified. R armscye is too far on body at the front - modified. Left shoulder higher than right. Very upright posture - swayback? Neck base and column girths not touching. Moved both wrist points. One breast lower than the other.	PW	ankle, wrist,	2	
31		19	bottom hourglass	26.4	A-white	Shoulder point too high - modified. Both front armascye point too far on the chest - modified	PW	armscye	1	
32		21	hourglass	24.9	A-white	Scan - chin is pointing upwards head held at an angle. Crotch point slightly high - modified. Neck base and column girth do not touch.	PW	crotch	1	
33		23	hourglass	31.2	A-white	Scan- subject has a heavy build with a slightly protruding abdomen and thick set thighs. R front armscye LM modified too far on chest. Modified L top arm and front scyed LMs. Thighs are touching. Subject has fat deposites around mid hip.	PW	armscye,	1	
34		23	bottom hourglass	21.9	A-white	L outside ankle use right	PW	n/a		

35	23	rectangle	21.2	A-white	Scan - subject is slim. R armscye girth looks incorrect and the grey surface view shows the surface as rough and pixcelated. The armhole top LM is too high on the shoulder & the front armpit LM too far over the chest - both modified. Neck base and neck column girth are not touching.	PW	armscye	1	
36	24	hourglass	24.4	A-white	not numbered in scanner properly - age missing check database. No change to LMs	PW	n/a		
37	24	rectangle	24.1	A-white	R ankle measure data missing go w	PW	n/a		
38	19	hourglass	20.8	A-white	no change	PW	n/a		
39	20	hourglass	18.2	A-white	Scan - subject is slim. R armhole top is a little low on the arm - modified. Neck base and neck column girths are not touching. L wrist too high on arm - modified.	PW	armscye, wrist	2	
40	19	hourglass	20.3		no issues	PW	n/a		
41	20	rectangle	28.9	A-white	Scan - subject is a heavy build and has fat deposites around the thighs, hips, abdomen, upper arms and across back. Breast points are high and subject has a definable waist. Thighs are touching. Crotch point too high - modified. Elbow on right arm too high - modified. R armscye LM at back incorrect as positioned too far over on arm - modified. Neck and column girths not touching.	PW	crotch, elbow, armscye	3	
42	19	triangle	22.1	A-White	CB neck point too high on neck - modified. Crotch point too high - lowered although this then effected W37 R outside ankle point (the crotch point is tied into the leg landmark positions. Use left ankle measures as cannot modifiy point.	PW	CB neck, Crotch	2	
43	20	hourglass	23.3	A-white	no change	PW	n/a		
44	22	bottom hourglass	22.4	A-white	Scan - subject is slim but displays larger hips to bust making them a triangle. Neck column and base girths not touching. Subject's breasts appear small and flat (side profile on) which has meant the underbust looks low on the body. Not modified as it is under the curve of the breasts. Largest hip measure finishes at the prominence of the buttocks but the thighs are wider beyone that point. Perhaps a combined thigh measure need to be taken for tight fitting skirts?	PW	n/a		
45	19	hourglass	30	A-white	Scan - subject has a protruding abdomen which hangs over the pant line. Bust point is high. Posture is upright and subject displays a well defined small of back curve. Subject has natural indentations at region of waist. L armscye front LM is slightly too far onto the body - modified. Occulusions under the armpit. Crotch too high - modified. Neck base and column girth do not touch.	PW	armscye, crotch	2	16as
46	20	hourglass	22.1	A-white	no change	PW	n/a		

47	20	bottom hourglass	28.8	A-white	Scan - R 38, L38, R 123 not handled - modified. Subject has excess fat around the high region. Subject displays natural indentation around the waist region. Slight occlusion at R armpit but armscye measure looks ok. Neck column and base girths not touching. Waist too high - modified.	PW	waist	1 waist
48	24	bottom hourglass	23.1	A-white	no change	PW	n/a	
49	24	rectangle	20.9	A-white	no change	PW	n/a	
50	20	bottom hourglass	26.9	A-white	Scan - ankle outside left (38) not handled - modified. L armscye girth LM are incorrect at top armhole and front armpit - modified. R shoulder slopes downward more than left. Neck column and base do not touch.	PW	ankle, armscye,	2
51	22	bottom hourglass	27.2	A-white	Scan - ankle to floor outside R&L not handled - modified. Subject is slim. Neck colmn and base girths do not touch.	PW	ankle	1
52	20	rectangle	31.6	A-white	Scan - subject has little definition between bust, waist and hip and is of a heavy build. Bust point is high so bust under bust and waist is spread evenly. Neck base and column girths touch. Head is held forward and there is a curve in the cervical and thoracic portions of the spine. No issues.	PW	n/a	
53	22	rectangle	23.3	A-white	Scan - subject has lingerie indentation at hips and buttocks. Neck column and base girths touch. R wrist incorrect - modified. Subject has a defined thigh gap although does not appear underweight.	PW	wrist	1
54	25	bottom hourglass	20.7	L - Asian	No issues	PW		
55	22	rectangle	29.1	A-white	R armscye front too far on chest - (	PW	armscye	1
56	25	bottom hourglass	27.5	A-white	Scan - Subjects narrowest point on the torso appear near the underbust. They have a thick waist which continues downwards to the low hip and buttock region. Armscyes are incorrect for both L&R - modified. Neck column and base girths do not touch. Underbust and waist are very close together. Waist is moved downwards lightly.	PW	armscyes, waist	2 including waist
57	23	hourglass	23.8	A-white	No issues	PW		
58	23	bottom hourglass	25.6	A-white	Scan - subject displays fat deposits around the abdomen and high hip region of the body, There is a visible indentation from .lingerie around this area. Crotch point too low as thighs are touching - modified. Ankle to floor inside left not handled - modified. L shoulder is square where as R has a slofter slope ankle. Posture is upright. Abdomen protrudes when viewed side on. Bust point is low on the breasts. Adjust crotch has thrown ankle measures out - modifying ankle measures. Neck base and column do not touch.	PW	crotch, ankle,	2
59	22	rectangle	25.7	A-white	Scan - Neck column and base girths do not touch. R elbow cir too high - modified. Waist girth is not placed at narrowest circumference but its position looks ok.		elbow	1
60	21	rectangle	22.5	A-white	no issues	PW		
61	19	rectangle	22.6	A-white	subject is slim, clearly defined wais	PW	crotch	1

61	19	rectangle	22.6	A-white	subject is slim, clearly defined wais	PW	crotch	1
62	23	hourglass	25.3	A-white	No issues	PW		
63	22	rectangle	17.9	A-white	Scan - No issues	PW		
64	25	hourglass	27.1	A-white	No issues	PW		
65	22	hourglass	24.5	A-white	Scan - subject armscye are too far on chest - modifiied. Crotch point error - modified.	PW	Armscye and crotch	2
66	20	hourglass	15.8	L-Asian	Armscyes too far on chest. Crotch point has data missing and is too high. Modified both.	AP	Armscyes, Crotch	2
67	21	hourglass	23.2	A-white	No issues	PW		
68	25	rectangle	20.7	A-white	Scan - L armscye incorrect - modified. armtpit R front modified.	PW	Armscye	1
69	23	hourglass	23.3	A-white	Scan - No issues	PW		

27 Appendix S

27.1 Shape Category File based on Lee *et al's* (2007) Female Body shape categorisation (FFIT) research. Excel sheet developed by S., Gill, K., Brownbridge & J., Spragg

The Excel sheet

	A	B	C	D	E	F
1		Bust [W102]	Waist [W108]	High Hip [W110]	Hip [W114]	Category
2	CM					#VALUE!
3						#VALUE!
4						#VALUE!
5						#VALUE!
6						#VALUE!
7						#VALUE!
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						

28 Appendix T

28.1 Entire sample re-clustered according to height

subject co	height grouping 142cm-149.9cm	body shape type
	149	rectangle
	149	triangle
	149.4	rectangle
	149.5	rectangle
	149.7	rectangle

height grouping 150cm-155.5cm	body shape type
150.5	rectangle
151.5	rectangle
152	rectangle
153	triangle
153.4	rectangle
153.4	rectangle
153.5	bottom hourglass
154	rectangle
154.3	rectangle
154.5	rectangle
155.5	rectangle

subject co	height grouping 156cm-159.9cm	body shape type
	156	rectangle
	156	rectangle
	156.2	rectangle
	156.4	rectangle
	156.4	rectangle
	156.9	bottom hourglass
	157	hourglass
	157	top hourglass
	157	rectangle
	157.5	top hourglass
	157.5	rectangle
	157.5	rectangle
	157.5	
	158	bottom hourglass
	158	hourglass
	158.5	rectangle
	158.7	rectangle
	158.7	rectangle
	159	rectangle
	159.1	rectangle
	159.1	top hourglass
	159.6	rectangle
	159.9	hourglass

subject co	height grouping 160cm-165cm	body shape type
	160	rectangle
	160	rectangle
	160	rectangle
	160	rectangle
	160.1	hourglass
	160.3	rectangle
	160.5	hourglass
	160.5	rectangle
	160.6	rectangle
	160.6	rectangle
	161	bottom hourglass
	161	hourglass
	161	
	161	bottom hourglass
	161	rectangle
	161	rectangle
	161.5	bottom hourglass
	161.5	rectangle
	161.5	rectangle
	161.5	rectangle
	162	rectangle
	162	rectangle
	162	rectangle
	162	rectangle
	162.3	bottom hourglass
	162.4	rectangle
	162.5	hourglass
	162.5	bottom hourglass

subject co	height grouping 165.1cm-168.7cm	body shape type
	165.1	bottom hourglass
	165.3	hourglass
	165.7	hourglass
	165.8	bottom hourglass
	165.9	bottom hourglass
	166	triangle
	166	triangle
	166	rectangle
	166.1	triangle
	166.2	rectangle
	166.3	bottom hourglass
	166.5	bottom hourglass
	166.5	
	166.5	bottom hourglass
	166.6	rectangle
	167	hourglass
	167	hourglass
	167	hourglass
	167.2	rectangle
	167.2	rectangle
	167.4	rectangle
	167.5	rectangle
	167.6	rectangle
	167.7	rectangle
	167.7	triangle
	167.8	hourglass
	167.8	triangle
	168	bottom hourglass

subject co	height grouping 168.8cm-174.5cm	body shape type
	169.9	rectangle
	170	hourglass
	170.7	rectangle
	170.9	bottom hourglass
	171	hourglass
	171	hourglass
	171	rectangle
	171	rectangle
	171.5	top hourglass
	172	rectangle
	173.5	rectangle
	174	rectangle

height grouping 174.5cm-	body shape type
175.2	hourglass
175.5	rectangle
176	hourglass
176.5	rectangle
178.7	bottom hourglass

height grouping 178.7cm-183.5cm	body shape type
179	rectangle
183.5	hourglass

30	162.8	hourglass	168	rectangle
31	163	triangle	168	hourglass
32	163	bottom hourglass	168	hourglass
33	163	rectangle	168	hourglass
34	163	rectangle	168.2	rectangle
35	163.2	bottom hourglass	168.2	rectangle
36	163.3	triangle	168.2	rectangle
37	163.7	rectangle	168.4	rectangle
38	163.7	rectangle	168.4	rectangle
39	163.8	hourglass	168.5	bottom hourglass
40	164	rectangle	168.6	rectangle
41	164	rectangle	168.7	rectangle
42	164.3	rectangle	169.9	rectangle
43	164.6	bottom hourglass		
44	165	bottom hourglass		
45	165	bottom hourglass		
46	165	rectangle		

47	165	bottom hourglass
48	165	bottom hourglass

29 Appendix U

29.1 TC^2 and Beazley and Bonds (2003) landmarks and measurement definitions

1			**Comparison of Landmarks and measurment defintions**			
2		**Measurement Name**	**Beazley and Bond (2004) definitions***	**TC[2] definition (MMU mep)¥**	**Landmarks used TC[2]**	**Landmarks used Beazley and Bond (2004)**
3	A	Bust Girth (W102)	Taken horizontally around the fullest part of the bust and parallel to the ground incorporating the shoulder blades.	A horizontal circumference measurement taken under the armpits (without arms) and over the most prominent point of the bust. Maximum circumference of the trunk at the greatest bust prominence level	Greatest bust prominence, greatest forward bust projection.	Bust prominence, shoulder blades
4	B	Waist Girth (W108)	360 viewing. Using a waist elastic. Natural position of the waist, not parallel to the ground.	Side view of person. Find the deepest point of the spinal curve at the tangiental change place back waist landmark any any point within a 4cm tolerance to locate the narrowest point on the torso.	The small of the back/point of tangential change.	narrowest circumference in the waist region determined by the elastic method.

5	C	Neck Base Girth (W87)	Starting with the nape postion a close fitting chain around the base of the neck.	Measured at the transition of neck to trunk.	7th cervical vertebra, side neck the point of tangential change between the neck column and the torso, front neck point	Nape, sternal notch as implied by photo in paper.
6	D	Back Neck Depth (W12)	Given a standard measurement of 2cm, no definition in the book. Common in pattern literature as not an easy measurment to take	Distance between centre back neck level and right neck shoulder point level.	7th cervical vertebra, side neck the point of tangential change between the neck column and the torso	not explicitly specified
7	E	Back Neck -2-Waist Length (W40a)	The tape measure is positioned at the nape (7th cervical) and placed vertically down the centre back to thelower edge of the waist level tape	Distance between the centre back neck point and waist level. Contoured over shoulder blade then straight to waist.	Spinal process of cervical vertebrae at the base of neck small of back and waist	natural waist level, 7th cervical

8	F	Armhole Depth/Scye Depth	Locate the nape of the neck and run a tape straight down the centre back Locate the bottom of the armpit and run a tape horizontally across the back until it intersects the vertical tape. Read the measurement.	Derived measurement. Vertical distance from the level of the Centre Base Neck straight to the arm base level. Arm base level /armscye underarm level: horizontal line passed under the armpits at the level of the underarm midpoint. Distance between right armhole long shoulder point and right underarm level.	Centre Base Neck and armpit level. Axilla. Acromion extremity	Nape of the neck, armpit bottom. Not specific only provides a picture.
9	G	Side Neck 2 Waist (over the bust)	Tape measure is positioned from the nape over the right shoulder at the neckline, then diagonally to the prominence of the right breast continuing downwards to the waist level. Half the back neck measurment is subtracted from this measurment.	Derived measurement. Locate the R side neck point, move over the body contours in a diagonal trajectory ending at the most prominent part of the R breast, then virtually straight to the waist level.	Upper Trapezius muscle, Nipple, Under Bust level (rib cage) and waist level	C7, Nape, bust prominence, waist level
10	H	Side Neck to Bust	Tape measure is positioned from the nape over the right shoulder at the neckline, then diagonally to the prominence of the right breast. Half the back neck measurment is subtracted from this measurment.	Distance from the base of the neck (shoulder neck point) to the breast point Measured from the neck shoulder point on the contour of	Shoulder neck point and breast point.	C7, Nape and bust prominence
11	I	Across the Back (W83)	A width measurement taken horizontally and gauged just above the skinfolds where the arms connect to the torso	Across Back Width. The width taken between the back left and right armpit points Contoured surface length (W83)	Back left and right armpit points.	axillia fold

12	J	Across the Front (W85)	The measurement is taken horizontally between the left and right skin folds where the arm connects to the torso. This is approximately midway between the centre front neck point and bust level.	Horizontal distance between the front armholes on the across front level – 2/3 of the depth of the armscye from the shoulder point level. Depth between the shoulder arm point and the underarm	1/3 of front armscyes height above the armpit	under arm level, neck point and fullest girth of the bust
13	K	Shoulder Length (W91)	The highest part of the shoulder is located and measured from the base of the neck to the bone at the end of the shoulder.	Distance from the base of the neck (shoulder neck point) to the shoulder point (acromion extremity) Measured in a straight line	Shoulder neck base point and acromion extremity	acromion-clavicular, position at the base of the side neck
14	L	Bust Prominence width , bust point distance (W86)	Measure horizontally between the most prominent part of the left and right breasts	Horizontal distance between the bust points.	nipples	bust prominence
15	M	Width of Armhole/scye width (W97)	Scye width, taken using calipers (Beazley, 1996). No information within the book.	Horizontal distance between the body contours of the upper arm viewed from the side Measured at the underarm midpoint level	Arm base at the transition to the trunk front and back in level of the armpit	not explicitly specified either in the book or in an early academic paper by Beazley (1996)

16	
17	
18	
19	
20	* definitions are from: Beazley, A., & Bond, T., (2003), *Computer-Aided Pattern Design & Product Development* , Blackwell Publishing, Oxford; Beazley, A., (1998), Size and Fit: Proceedures in Undertaking a Survey of Body Measurements, *Journal of Fashion Marketing and Management* , 2 (1), pp. 55-85
21	Bougourd, J., (2002) *Proposed Human Body Measurement Standard* , (online) http://www0.cs.ucl.ac.uk/staff/p.treleaven/BodyMeasurements.pdf, *(accessed, July 2013)*
22	
23	The measurement definitions appear at different points on the torso for waist, armhole depth, x front and back which have impacted on the pattern. A new pattern method needs developing specific to scanner definitions.
24	

30 Appendix V

30.1 Participants selected for bodice pattern construction and their body dimensions spreadsheet

Selected sample for pattern generation

Subject code	subject shape	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	(b) W108 Waist girth original	(b) W108 Waist girth cleaned scan	(c) W87 Neck base girth original	(c) W87 Neck base girth cleaned scan	(d) W12 Back neck depth (back neck rise)original	(d) W12 Back neck depth(back neck rise) cleaned scan	e [40a]-BkNeck-2-WaistLength-(e) original	e [40a]-BkNeck-2-WaistLength- (e) cleaned	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	h [??]-SideNeck2 Waist-overbust-(h) original	h [??]-SideNeck2 Waist-overbust-(h)cleaned	g [??]-SideNeck2Bust-R-(g) original	g [??]-SideNeck2Bust-R-(g) cleaned	I W83 Xback before cleaned	I W83 Xback after cleaning	j W85 X frnt before cleaning	j W85 X frnt after cleaning
	triangle	119.26	119.27	107.25	108.84	42.57	42.57	2.00	2.00	38.13	40.33	21.83	21.83	43.50	44.97	34.21	34.20	37.79	37.79	41.37	41.37
	bottom hc	98.59	98.44	75.55	77.88	38.40	38.04	2.00	2.00	35.49	37.06	17.06	17.56	41.23	42.34	29.08	29.29	33.04	32.14	29.24	27.05
	rectangle	116.39	116.63	99.16	100.69	42.00	42.00	2.00	2.00	41.90	43.33	22.82	22.82	46.06	47.37	33.52	33.52	39.40	39.40	39.70	45.06
	rectangle	101.16	101.16	87.70	88.34	37.61	37.61	2.00	2.00	37.86	39.05	18.55	19.55	41.04	42.15	27.69	27.69	27.18	32.65	37.48	37.49
	bottom hc	105.70	105.70	87.72	90.45	43.68	43.68	2.00	2.00	37.28	39.16	15.55	15.55	44.11	45.68	32.04	32.04	29.59	29.59	42.64	42.64
	rectangle	88.19	88.19	71.84	71.84	36.54	36.54	2.00	2.00	40.30	40.30	12.97	12.97	41.27	41.27	25.53	25.53	32.34	32.34	30.26	30.26
	hourglass	108.22	109.24	86.20	86.20	39.94	39.94	2.00	2.00	40.64	40.64	17.36	17.36	44.07	44.07	26.96	26.96	33.00	33.00	33.30	40.43
	bottom hc	96.02	96.57	78.65	80.80	36.37	36.38	2.00	2.00	34.45	36.05	14.97	17.48	41.54	42.42	30.06	30.06	27.21	32.77	32.02	37.81
	bottom hc	95.11	95.11	80.77	80.77	37.51	37.51	2.00	2.00	37.76	37.76	16.93	16.93	39.09	39.09	27.36	27.36	32.11	32.10	37.20	37.20

k W91 R shoulder length before cleaning	k W91 R shoulder length after cleaning	LW86 bust to bust before cleaning	L W86 bust to bust after cleaning	m W94R width of armhole before cleaning	m W94R width of armhole after cleaning
14.84	14.84	26.46	26.46	14.77	14.77
10.90	11.60	19.57	19.57	13.32	13.32
15.00	15.57	23.61	23.61	13.8 (L)	13.50
11.92	11.92	23.45	23.45	15.41	14.82
12.42	16.20	23.99	23.99	17.68	17.68
10.57	13.50	17.08	17.08	10.48	10.48
9.25	13.10	23.49	23.49	18.86	15.32
7.84	14.90	21.28	21.28	17.53	13.30
13.44	13.44	23.12	23.12	12.33	12.33

31 Appendix W

31.1 Pattern validation notes for 9 selected scans

Pattern Observation notes

Subject code	subject shape	BMI	Pattern Observations (unmodified)	Pattern Observations (modified)
FA65	triangle	37.3	The armscye looks large although the participant is not small. The front armscye shaping looks flat. This is because the shoulder is too short and the method requires that the shoulder cuts through the horizontal 6cm line to give a shorter angle of 22 degrees. A fitting will confirm if this angle is sufficient although the subject has not got extreme kyphotic posture. The back armscye shaping looks too long at the underarm. Consequently the balance of the side seam looks slightly too far forward. Neck looks a little deep at the front. The body darts have had to be modified from the presecribed method as the 4,3,4cm spread does not give sufficinet ease for the waist. Bust points sit low but then again the person has a large breast. The front bodice dips deeply when compared to the back. This is because the measurement included a contoured measurement over the bust from the side neck point was added in as one of the last measurments to complete the shaping of the waist line.	The armscye shaping looks improved and the shaping is flatter on the back arm hole and gently scooped out at the front armhole which is what is expected on a pattern. The back bodice looks wider at the underarm than the front and this could be because of how the side seam is placed. The participant is carrying weight around the bust region and not the shoulders which makes the pattern look at little distorted. A fitting will determine the true success of the pattern fit. Bust point is low but again the breast is large and sitting lower on the torso. Front bodice dips but is approc 1.5cm less than on the raw pattern.
FA55	bottom hourglass	25	Problems with armscye shaping. Back armhole looks too flat around the top of the armhole. This is because the shoulder is too short. The centre front dips significantly at the waist due to measurement G. Body darts and side seam have been modified to give sufficient ease as recommended by the method.	Shoulder still look to narrow on pattern although a fitting will determine their comfort. Back armhole is still very flat around the top of the armhole. The front dips more on the modified scan and looks a lot longer than the abck due to measurement G. Body darts and side seam have been modified to give sufficient ease as recommended by the method.
FA70	rectangle	29.1	Front bodice looks elongated and narrow. The back is ok. The front armhole curve looks too shallow. Bust point is low, almost 10cm below the underarm level. Centre front dips due to measurement G. body darts and sideseam shaping need modification to allow more ease.	Armhole looks better as shoulder length has increased by 0.6cm. Front armhole shaping still a little flat due to it needing to touch the front armhole horizontal line. The shape would probably be imporved if the curve could sit slightly outside of this line. The side seam is sitting a little too far on the the front bodice but again a fitting of the bodice will indicate if the side seam is in the correct place. Centre front doe not dip as much as on the raw scan probably because the waist landmark is moved using the centre back landmark.The body darts and side seam has been modified to create sufficient ease.

fa35a	rectangle	24.1	Back armhole shaping looks too deep and curve too scooped around the fold of the arm. The side seam looks too far towards the front. The front armhole looks too shallow. The shoulder is too narrow?	The back shoulder angle is a little steep and there is little curved shaping around the top edge of the back armhole. Front armhole shaping is improved. Body darts and side seam shaping modified to provide sufficient ease at the waist.
fg43_	bottom hourglass	30.1	There are problems with the armscye shaping. The curve of the armscye cannot be achieved within the framework of the method ie the back curve cannot touch the back armhole and the front curve is dragged twoards the centre front and not touching the front armhole vertical line in the right place. the bust is large in circumference and is the armhole and shoulder look skewed in relation as they are small and shallow. Shoulder look too short. The centre front of the pattern dips significantly because of measurement G. Bust point look low. Maybe too much ease on the front of the bodice? Body darts and sideseam shaping needed modification for sufficient ease at the waist.	Shoulder length is increased and the armhole shaping looks improved but the front armhole still does not cross the front vertical armhole indicator at the recommended point according to Beazley and Bonds method. Back armhole looks too scooped out. Front armhole looks too shallow.Front bodice dips even deeper at the CF due to measurement G. There is a large occlusion at the underarm on this scan which is only visable if the bust is viewed as a slice. Slices need to be looked at as part of the cleansing protocols on participants with large breasts and upper arms and excess fat deposits on the back.
)fa36_	rectangle	21.4	Problems with the armscye area. Armhole looks a little small and armhole level on the scan looks high. Back should angle looks steep and too short. Front shoulder look too short after subtracting the shoulder dart. Body darts and side seam shaping modified to provide sufficient ease at the waist.	Problems with the armhole shaping and shoulder - it looks worse than the raw scan. The back armhole looks too scooped out. This is because the curve around the side seam from front to back was too shallow and made the armhole look too flat at the underarm. The curve was extended passed the armhole level to give more room at the underarm and to improve the shaping of the armhole which has resulted in the back armhole being too scooped out. When on the shaping may appear to look like the armhole is cut away and would present problems with set in sleeves. Front scooped area looks ok but as the method required the curve of the armscye to touch the front and back armhole vertical lines again this has made the scoop deeper than it should be.
fa23_	hourglass	31.2	Problems with the shaping of the armscye. The shoulder is too narrow and has distorted the armhole shape. The pattern looks more like a sleeveless cut-away armhole design. Back armhole is too scooped around the fold of the arm and flat at the top of the arm near the shoulder. The armhole has a wide scoop. Near armholes touch the back and front armhole vertical measurement guides. The placement of the side seam looks erroneous as it is placed more towards the back bodice. It is doubtful the side seam would side at the underarm althought this person has a large breast.	Armscye is less wide but still looks wrong according to the images and directions prescribed by the method. Back armhole too scooped and at the front armhole the shoulder does not cross the front armhole line as recommended by the pattern. Neck looks narrower on this pattern.

621fa25a	bottom hourglass	27.5	Problems with the shoulder length. Shoulder is far too short and as a result is impacting on the shaping of both back and front armholes. The method requires that the armhole curve should touch the vertical line for both front and back armholes to determine the armhole width. As the shoulder is so short the curve can only cross these lines near the base of the armhole. When fitted this block would look like a cut-away sleeve and would be problemative for set in sleeves. The front bodice dips very deeply and the centre front because measurement G (side neck 2 over bust to waist) is a much longer measurement than the nape to waist measurement. Body darts and side seam shaping is modified to create another ease for the waist. Bust point looks low.	Much improved armscye shape due to the modification of the shoulder measurement which is now longer. The waist is still dipped deeply at the front but again this is because measurement G is a significantly longer measurement than nape to waist.
669fa23_	bottom hourglass	25.6	Front armscye shaping is too flat. The shoulder is too narrow and does not extend beyond the 6cm horizontal line developed to give a 22 degree angle to the shoulder. This has meant the curve sits mainly inside instead of outside the front armhole vertical line. Back armhole looks ok.	Shoulder lengthen and has resulted in better front armhole shaping as the curve can now almost touch the vertical front armhole line.

MI scores	colour code
nder weight	
leal weight	
verweight	
bese	
ery obese	

ll patterns have been vertified by an experienced pattern cutter and academic (30 years experience). Comments have arisen from consultation with hem. General comment were armhole shaping problematic, method does not allow for different body types, bust point looks low and measurement G as meant the front bodice dips and has made the waist shaping deep. The method prescribes to measures dependant on the centre back line (S Gill, thesis

height group from 153-153.5
height grouping from 165.1-166.5
height grouping all 165

29

32 Appendix X

32.1 Participant consent to fit and photograph the toile

Manchester Metropolitan University

HOLLINGS FACULTY - RESEARCH ETHICS

Any research undertaken by the student stated below will be conducted, recorded and presented in accordance with the guidelines set out by the University Academic Ethics Committee. These guidelines are known as the MMU Academic Ethical Framework and may be accessed at: http://www.rdu.mmu.ac.uk/ethics/mmuframework.htm.
They are compatible with those published by the ESRC and other responsible bodies.

Name of student: ....

Project/Dissertation title: ....

Student statement:

Before any research is undertaken, I would like to assure collaborators and participants of the following points:

- Participation in an interview is entirely voluntary.
- Participants are free to refuse to answer a question at any time.
- Participants are free to withdraw from an interview at any time.
- The interview/questionnaire will be kept strictly confidential and will be available only within Hollings Faculty.
- Excerpts from this interview/questionnaire may be incorporated into a project report or dissertation, but under no circumstances will names or personal characteristics be included without prior consent.

Signed: .... Print Name:..................................

Interviewee acceptance:

Signed: .... Print Name:..................................

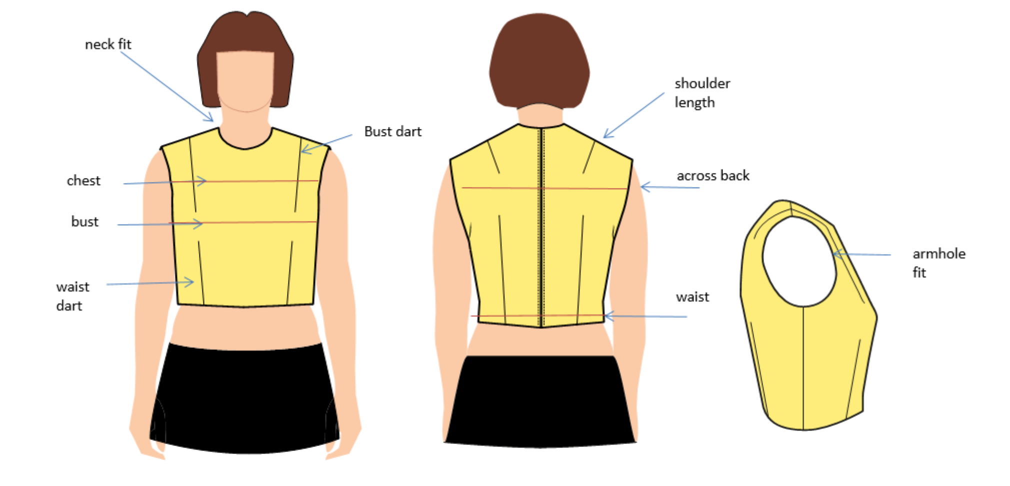
Date: ....

THIS IS YOUR COPY TO KEEP

33 Appendix Y

33.1 Participant feedback on toile fit pro forma

Participant bodice fit checklist						
Name			**Bodice** (researcher to complete)			
	very tight	**tight**	**ok**	**loose**	**very loose**	**comments**
Neck opening						
chest width	**very tight**	**tight**	**ok**	**baggy**	**very baggy**	**comments**
Back width	**very tight**	**tight**	**ok**	**baggy**	**very baggy**	**comments**
bust circumference	**very tight**	**tight**	**ok**	**loose**	**very loose**	**comments**
bust dart length	**very short**	**short**	**ok**	**long**	**very long**	**comments**
bust shape positioning	**very high**	**high**	**ok**	**low**	**very low**	**comments**
waist circumference	**very tight**	**tight**	**ok**	**loose**	**very loose**	**comments**
waist dart length	**very short**	**short**	**ok**	**long**	**very long**	**comments**
waist positioning	**very high**	**high**	**ok**	**low**	**very low**	**comments**
shoulder length	**very short**	**short**	**ok**	**long**	**very long**	**comments**
armhole fit (around the armpit)	**very tight**	**tight**	**ok**	**loose**	**very loose**	**comments**



Do you prefer this bodice?	comments

developed and informed using the following papers:

Petrova, A., & Ashdown, S., P., (2012) Comparison of Garment Sizing Systems, *Clothing and Textiles Research Journal,* Vol 30(4), 267-284
Richards, M., L., (1981), The Clothing Preferences and Problems of Elderley Female Consumers, *The Gerontologist,* Vol 21(3), 263-2676
Ashdown, S., P., & O'Connell, E., K., (2006), Comparison of Test Protocols for Judging the Fit of Mature Women's Apparel, *Clothing and Textiles Research Journal,* Vol 24(2), 137-146

34 Appendix Z

34.1 Pictures of toile fitting

Bodice one unmodified scan

Bodice two modified scan

Bodice one unmodified scan




35 Appendix AA

35.1 Case study transcriptions, notes and artefacts

35.1.1 Correspondence one

Paragraph #	[redacted] **meeting 18 April 2013 minutes**	**Main Themes**	**Associated words**
	Present at the meeting:		
1	[redacted], [redacted], [redacted], [redacted], [redacted]	Three people attended from the company. Two marketing and one garment technologist	Marketing was more involved as more attended the meeting.
	Summary from [redacted]		Marketing executive
2	*To explain a bit more about the activity I'm working on, we are hoping to set up a body scanner booth at a public exhibition/ event to use as a PR stunt as well as a consumer recruitment tool. Visitors to the stand would be able to have their body scanned and then we'd help them input the data into our virtual fitting room which is run in partnership with a company called Metail, this records the customer's height, bust, waist and hips measurements and recommends the right size to order in each individual*	**Marketing, Aims and achievements customer engagement,** their goals increase sales, **scanner utilisation** 'marrying' bodyscanner with another technology	**Marketing** – PR stunt, public exhibition, consumer recruitment. **Aims and achievements** – Our aim, customers' confidence, range cut to fit proportions, buy right size

	product. Our aim is for customers to have confidence that the Savoir range is cut to fit their correct proportions and buy the right size first time.		first time. **Scanner utilisation** – body scanned, data **Positive about technology –** recommends right size. **Customer engagement –** help input data
3	*We are currently considering Women's Weekly Live as a potential venue as we sponsored this event last year and the demographic match perfectly with our target audience, this event takes place over 3 days at Event City, Manchester in September although we are also exploring alternative events to ensure we get maximum exposure with the right audience.*	**Marketing, Time and cost**	**Marketing –** demographic match perfectly, maximum exposure, right audience. **Time and cost –** sponsored, 3 days, maximum **Research –** exploring, alternative events

4	*It would be great to discuss in more detail and get a rough understanding of the costs involved. I'm available on* [redacted] *during office hours (roughly 8:30am – 5:30pm) or on my mobile* [redacted] *outside of those hours so please feel free to get in touch anytime.*	**Time and cost**	**Time and cost –** costs involved, discuss more detail, rough understanding
5	Dates of exhibition Womenswear Weekly, 13-15 September, Event City (Trafford Park), 10:00-5:00pm. The venue will have a fit lounge, buying area and body scanning area		
6			
7	Discussed:		
8	Womenswear Weekly customers 45-80	**Research**	
9	[redacted] brand – targeted at 50-65, block have been specifically designed for the changes in body shape. Block development	**Marketing, Research**. Their understanding of their market. Their actions to improve the product.	**Marketing –** targeted 50-65, specifically designed for changes in body shape. **Research –** block development
10	Colour coded tape measure (ASOS)	**Research & Marketing**	**Research –** colour coded

11	Metail technology uses avatars	**Research** Comparing with bodyscanner	**Research –** technology, avatars
12	Metail measures the garment and links garment measures to customers	**Positive about technology.** They did not question its effectiveness. They had already b ought into it.	**Positive about technology –** measures, links, customers
13	Linking Metail technology measurements (4 measures height,bust,waist and hip)	**scanner utilisation.** They understood the scanner take body measurements.	**Scanner Utilisation –** linking, technology, measurements
14	Look on Very to see how Metail technology works	**Positive about technology.** Tried and tested in their opinion.	**Positive about technology –** Look, Metail, technology, works
15	Amounts of people to get through scanner – suggested 20 hour but more like 10 an hour	**Time and cost**	**Time and Cost –** amounts, people, get through, 20/hour

16	Branding the scanner	**Marketing**, the public must see ISME's logo on the scanner. Demonstrating the company is openly using technology for what they feel are positive customer results.	**Marketing –** Company Branding
17	Building a scanner frame to secure valuables	**Marketing** **Privacy**	**Marketing –** building a frame **Privacy** - secure
18	Customising meps, using the SizeUSA mep initially. Then reducing the measurements to 4 measures for the customer output which will tie into the Metail technology.	**Scanner utilisation** **Positive about technology**	**Scanner utilisation –** customising, reducing, customers output, **Positive about technology –** tie into, Metail
19	Can the order of the measurements be changed?	**Scanner utilisation**	**Scanner utilisation –** order, measurements changed

20	We require measurement definitions from [redacted] – will these be clothing?	**Logistics**	**Logistics-** measurement definitions
21	A more accurate costing is needed for 4 weeks time.	**Time and cost**	**Time and cost –** accurate, cost, 4 weeks
22	A further meeting is planned for 4 weeks from this date – mid June. This meeting will entail further discussions regarding the scanner size and transportation.	**Time and cost**	**Time and Cost** – 4 weeks
23	Students will need recruiting via jobsforstudents.	**Time and cost**	
24			
	<u>Notes:</u>	**<u>Notes from scan team</u>**	
	Require a costing for this project (in order requested)		
	Setting up project, custom MEP output, branding of scans		
	1 day promotional activities		
	Actual scanning approx. 5 days		
	Clean and present data		

Coding information

Themes	Count of main themes
Pink – Marketing	4
Yellow – Scanner utilisation	4
Green – Aims and achievements	1
Blue – Time and cost	5
Purple – Engagement with the customer	1
Red - Company research	5
Grey - Positive about technology	4
Olive - Privacy	1
Teal - Logistics	1

Italics – represents the company's own words

Non-italics – represents the scan teams words

Anonymous font – field notes of conversations and actions from both parties

Paragraph 5
There is a slight contradiction here using the words detail and then rough. This indicates they are interested in further discussion to increase their understanding but that the university does not need to be exacting in terms of cost at this point.

Paragraph 6

Venue had been settled on prior to meeting. Indicating the first email was exploratory initially and at the stage of the meeting firmer plans had been made.

Paragraph 8

This list was kept in the order each item was discussed on the day. The company began by explaining who their customer is (marketed in red).

Paragraph 10

During the meeting block development was discussed alongside body shape change, they were aware that women lost height, had a curved spine and a more rectangular shape. They also believed the crotch pitch changed whereby the pelvis tilts so the bottom appears flatter and the hips are drawn upwards. They asked if the university concurred with this.
The scans would provide evidence of this. No physical evidence of this was presented at meeting.

Paragraph 11

They are aware of what other retailers use for gathering body sizing information. Colour coding replacing the number codes

Paragraph 12

They had already bought into this technology and their discussion about it was positive. They did not go into too much detail about how it worked, they expected we already understood its application.

Paragraph 19

Body dimensions not specifically discussed

Paragraph 21

Company could not provide measurement definitions at the meeting even though garment tech person present.

35.1.2 Correspondences 2

Paragraph #	Email correspondence from 28 May 2013	Main themes	Associated words
1.	*Hi [redacted], yes we will see you next week*		
2.	*Thanks*		
[redacted]	[redacted]		
4.			
5.	senior online marketing executive [redacted]		
6.	ex 2533		
7.	From: [redacted] [mailto:[redacted]]		
8.	Sent: 28 May 2013 09:44		
9.	To: [redacted]; [redacted]		
10.	Cc: [redacted]		
11.	Subject: RE: [redacted] has shared 'Sizing Graphs to Share [redacted] with you using Dropbox	**Communication**	**Communication** – share, Dropbox
12.			
13.	Hi [redacted]		
14.	Just to confirm we will be meeting next Wednesday (5th June) between 10-12. I hope you received the images with the previous email.	**Communication**	**Communication – ** confirm, meeting, hope received, images, email
15.	Please also find a link to a video explaining the possibilities with the scan data in terms of outputs http://youtu.be/gZQOvpVEbsg	**Scanner Utilisation** **Communication**	**Scanner Utilisation –** possibilities, scan, data, outputs **Communication** – find, link, video, explaining
16.	I look forward to meeting with you again next week		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	1
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – scanner accuracy	
Brown - communication	3

Italics – represents the company's own words

Non-italics – represents the scan teams words

Anonymous font – field notes of conversations and actions from both parties

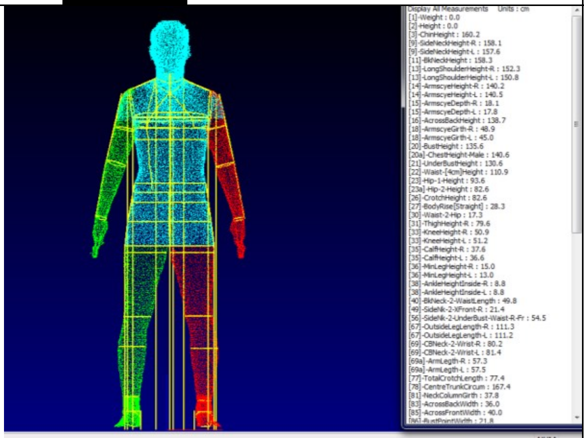
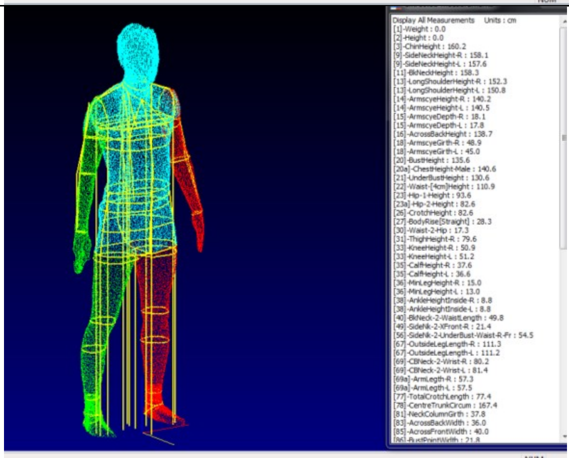
Paragraph 2

Short reply, confirming a meeting. No indication the attached link has been watched or the images viewed. The company asks no questions in this email

Paragraph 5
Communication is still between scan team and the marketing department

Paragraph 14
As communication is reliant on emails at this point the sender checks everything has been received as the previous email on the 14 May was not acknowledged in a timely manner.
Team check the company can view images as it will further their understanding of the technology.

35.1.3 Correspondence three

Paragraph #	Email 14 May 2013	Main Themes	Associated words
1.	A scan from the 1st [redacted] meeting. Reps from [redacted] requested this image be sent on to them in a format that they could view. They were sent [redacted] as screen shots.		
2.			
3.			
4.	In this correspondence [redacted] also shares sizing graphs. See below for correspondence		
5.	[redacted]		
6.	*I can't see the original email but we should be fine to reschedule from the 29th, when would be better for you?*	**Communication**	**Communication** – can't see, email
7.	*On an additional note, I am going to be moving roles within [redacted] in a couple of months and so my colleague [redacted] will be running the Women's Weekly Live event, I'll still be involved to some degree but [redacted] will be the main point of contact. We'll both come along to the next meeting but if you could include us both on any emails going forwards that would be great.*	**Communication**	**Communication –** moving roles, colleague, running, event, main point of contact, include us both, emails
8.	*Finally, would it be possible for you to send over an electronic copy of [redacted] bodyscan image? I am looking to include this in an internal presentation and the paper copy isn't*	**Marketing** This indicates that information on body scanning	**Marketing –** presentation

	scanning in very clearly so if you were able to access an electronic version or even a screen shot that would be much clearer	technology is to be cascaded to other company personnel via a presentation. The fact that the image needs to be clear suggests the image maybe scrutinised further during the presentation. **Communication**	**Communication** – paper copy isn't scanning, clearly, access electronic version, screen shot, much clearer
9.	*Thanks*		
10.	[redacted]		
11.	senior online marketing executive - [redacted]		
12.	ex [redacted]		
13.	**From:** [redacted] **Sent:** 14 May 2013 16:26 **To:** [redacted] **Subject:** FW: [redacted] 'Sizing Graphs to Share [redacted].docx' with you using Dropbox		
14.	Hi [redacted]		
15.	Please see below, I was hoping to reschedule, if this is not possible then I can still meet on the 29th	**Communication**	**Communication –** hoping, reschedule, not possible, still meet.

Themes	Count of main themes
Pink – Marketing	1
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	

Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Drk grey– scanner accuracy	
Brown - communication	4

Italics – represents the company's own words

Non-italics – represents the scan teams words

Anonymous font – field notes of conversations and actions from both parties

Paragraph 7

This colleague was from the marketing department

35.1.4 Correspondence four

Paragraph #	**Agenda for second [redacted] meeting sent by [redacted] the company**	**Main Themes**	**Associated words**
1.	**From:** [redacted] > **To:** [redacted] **Cc:** [redacted] **Subject: agenda for bodyscanner meeting tomorrow @ MMU**		
2.	*Hi* [redacted] *I just wanted to confirm the agenda for tomorrow so we make sure we cover everything off in the meeting:*	**Communication**	**Communication** – confirm, agenda, make sure, cover
3.	*· SDG (*[redacted]*) to provide guide on measurements required and data output format*	**Scanner utilisation** **Communication**	**Scanner utilisation –** measurements required, data, output, format

			Communication – provide, guide
4.	· *MMU to confirm customer print out format with cut down measurements*	**Scanner utilisation** **Communication**	**Scanner utilisation –** customer printout, cut down measurements **Communication** - confirm
5.	· *Discuss physical scanner 'staging' requirements at WWL*	**Marketing** – this refers to the event set design. **Communication**	**Marketing –** staging **Communication -** discuss
6.	· *Discuss staffing at WWL*	**Logistics** **Communication**	**Logistics –** staffing **Communication -** discuss
7.	· *Confirm budget*	**Time and cost** **Communication**	**Time and cost** – budget **Communication –** confirm

8.	· *AOB*		
9.	*Please let me know if there is anything you would like to include in this or we can pick up any bits and bobs in AOB*	**Guidance and confirmation**	**Guidance and confirmation –** anything, include, pick up, bits and bobs
10.	*I have also attached some early visuals of the 'virtual fitting room' we are looking to launch ahead of the bodyscanner event, this is the tool we will help customers to complete once they have been scanned so they can use their measurements to generate an accurate size recommendation. At this stage there are still some refinements needed but this will give you an idea of what it will look like that we can talk through tomorrow* *Many thanks and see you tomorrow* [redacted]	**Marketing, Positive about technology** **Engagement with the customer** **Aim and achievements** **Communication**	**Marketing –** virtual fitting room, launch, bodyscanner event **Positive about technology –** help, generate, accurate size recommendation, still some refinements needed **Engagement with the customer –** help, customers, complete **Communication –** give, idea,

			look like, talk through

[redacted]

senior online marketing executive - [redacted]

[redacted]

[redacted]

Themes	Count of main themes
Pink – Marketing	2
Yellow – Scanner utilisation	2
Green – Aims and achievements	1
Blue – Time and cost	1
Purple – Engagement with the customer	1
Red - Company research	0
Grey - Positive about technology	1
Olive - Privacy	0
Teal - Logistics	1
Navy - Guidance and confirmation	1
Brown - Communication	7

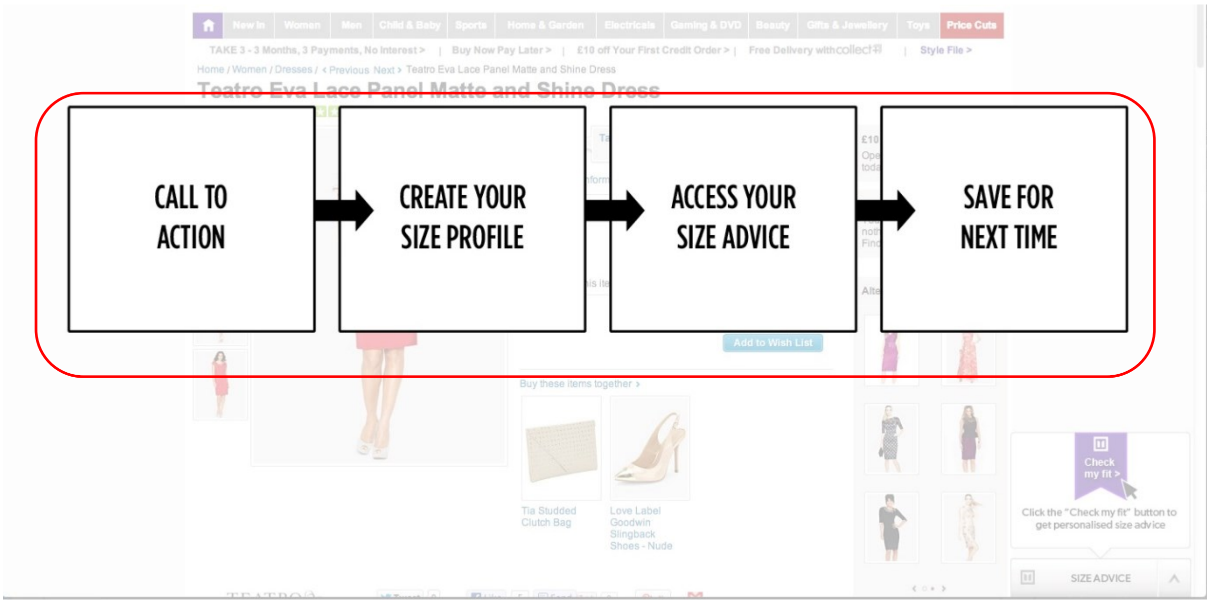
Italics – represents the company's own words

Non-italics – represents the scan teams words

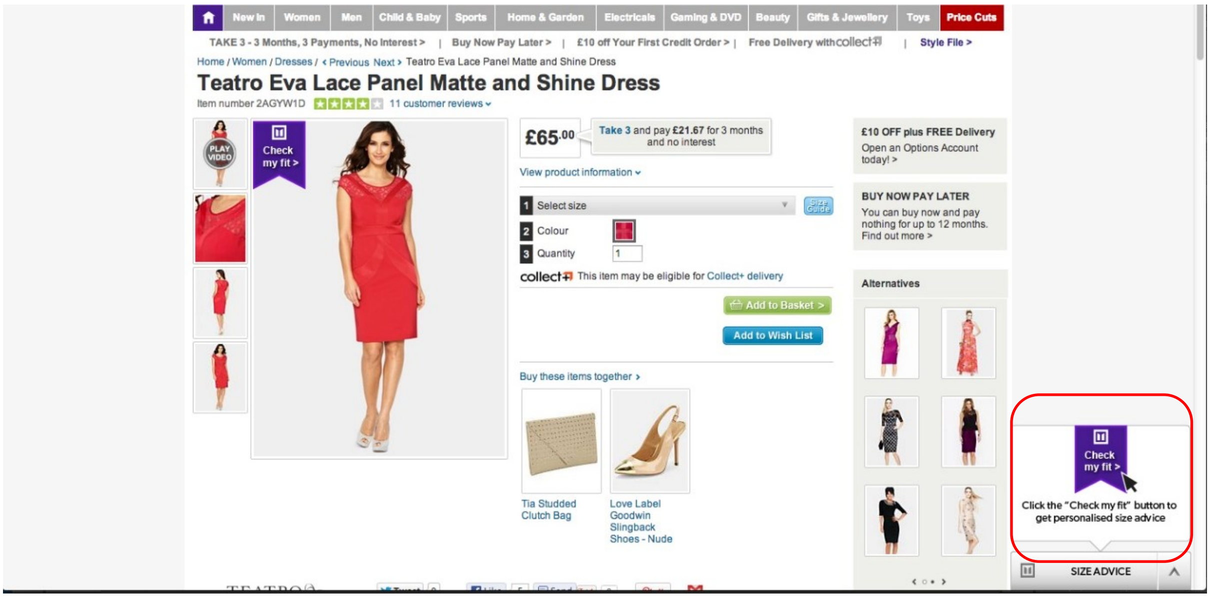
Anonymous font – field notes of conversations and actions from both parties

Virtual fitting room marketing images (communicated and send as jpegs to MMU)

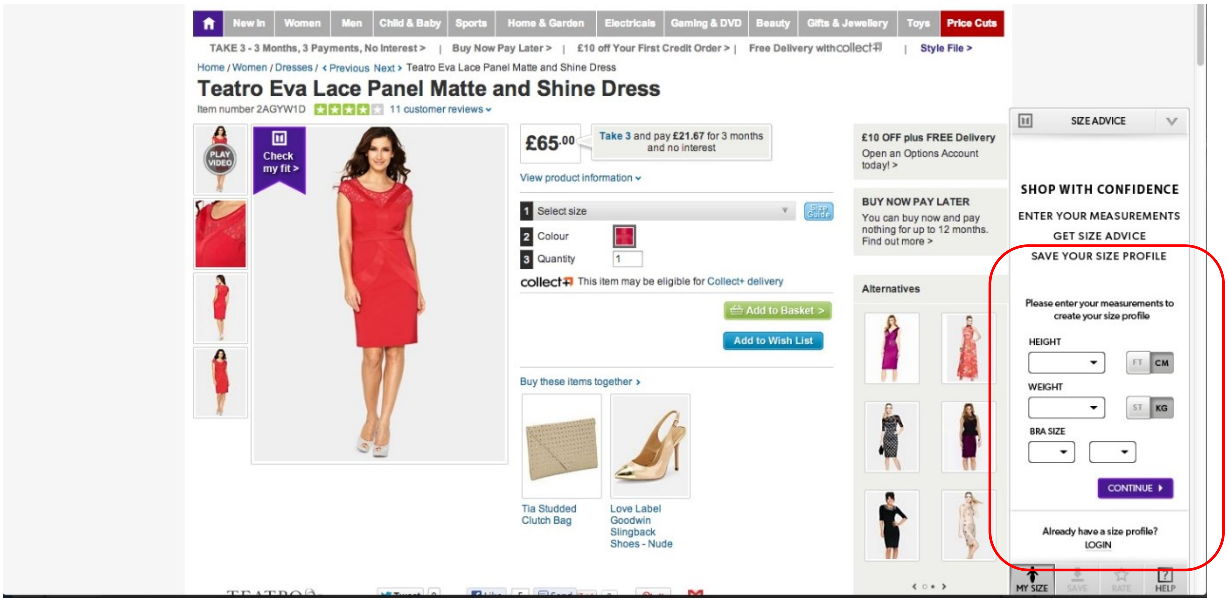
This is Metail.



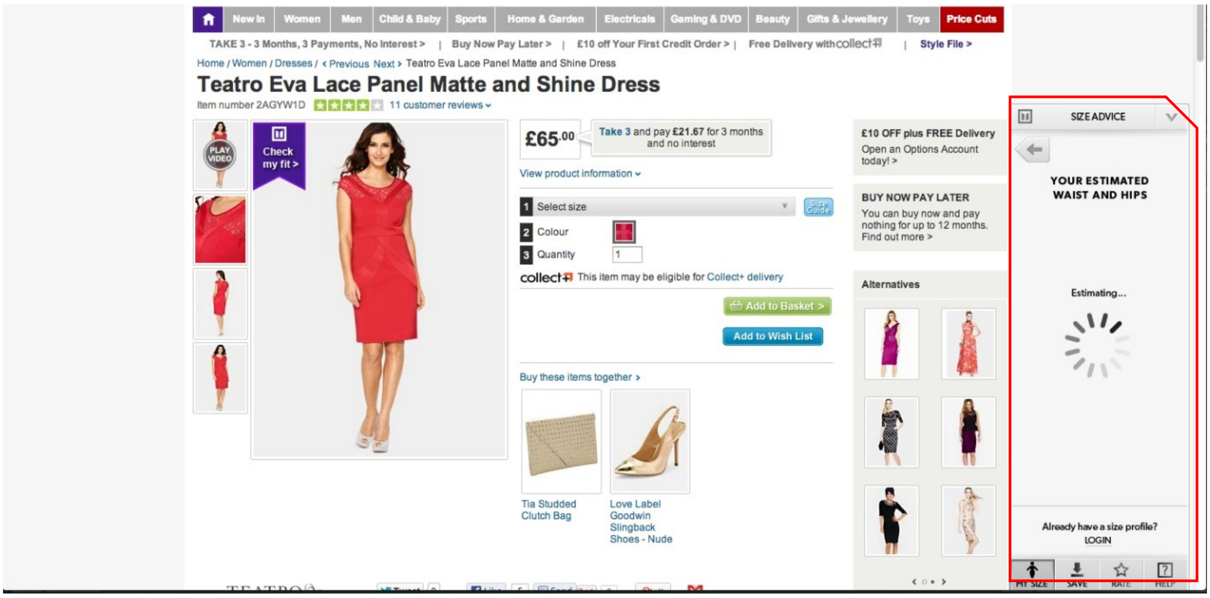
Metail a



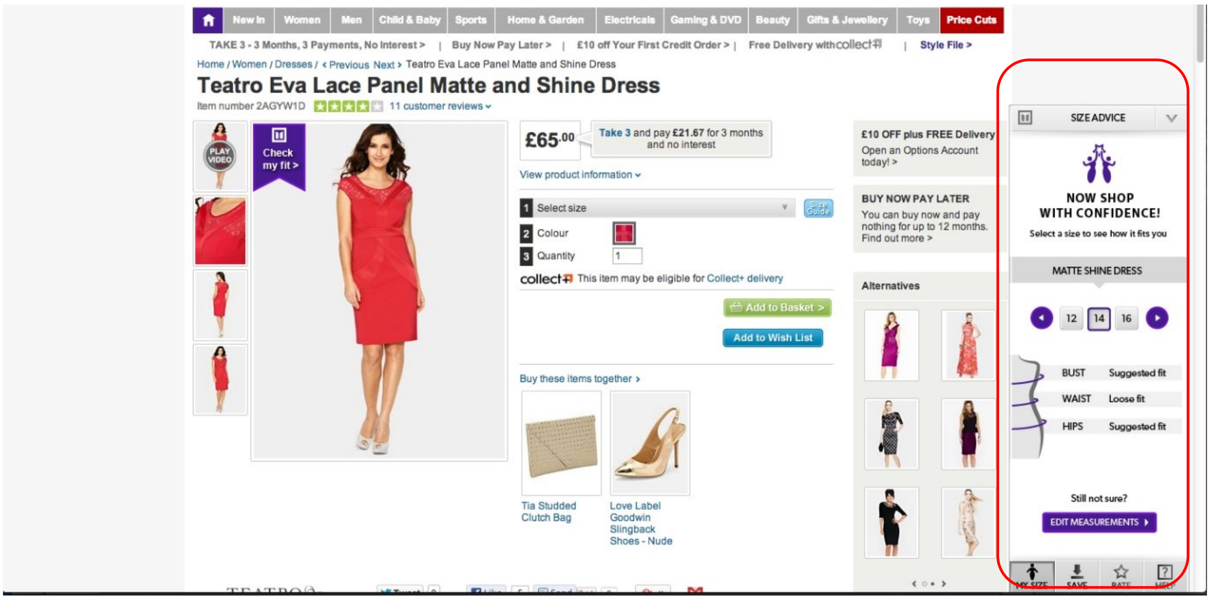
Metail B



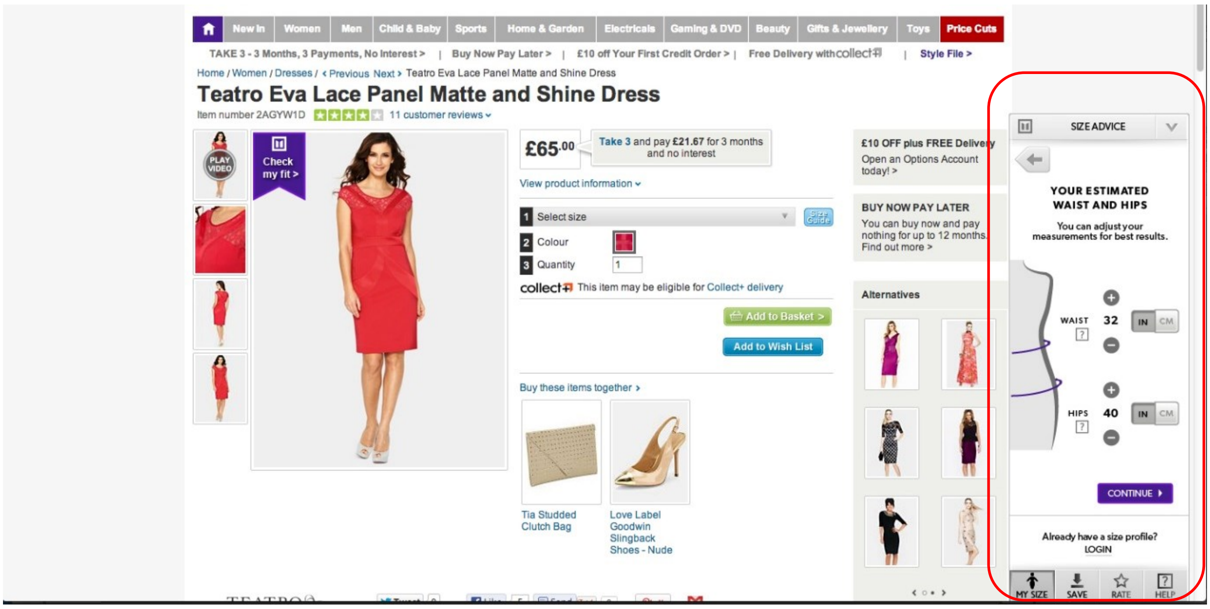
Metail c



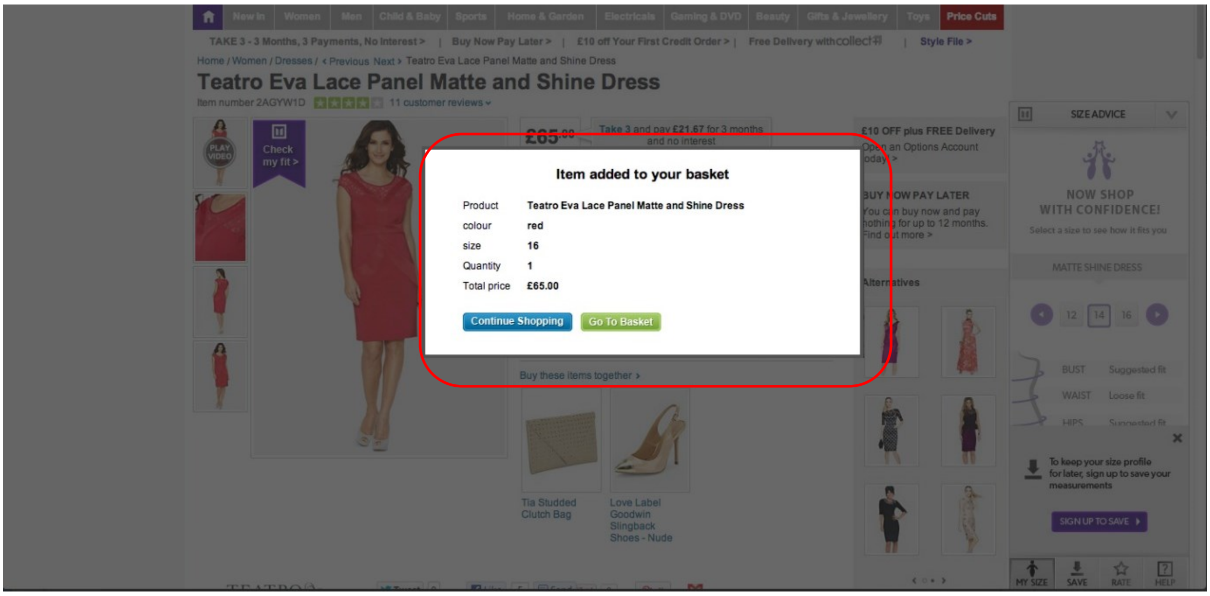
Metail d



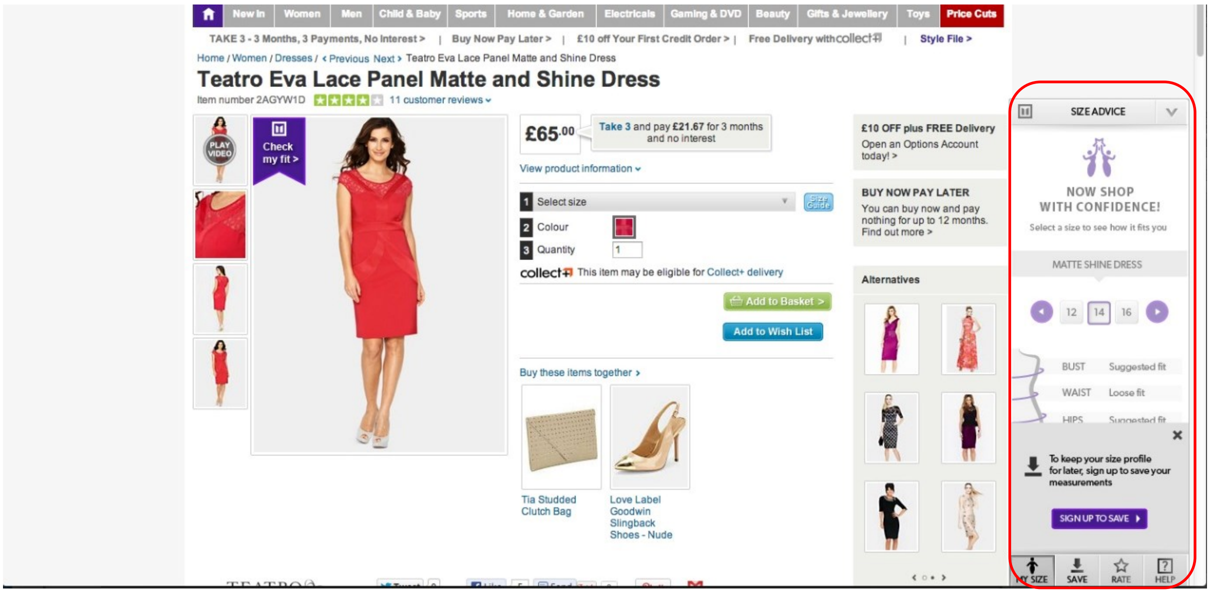
Metail e



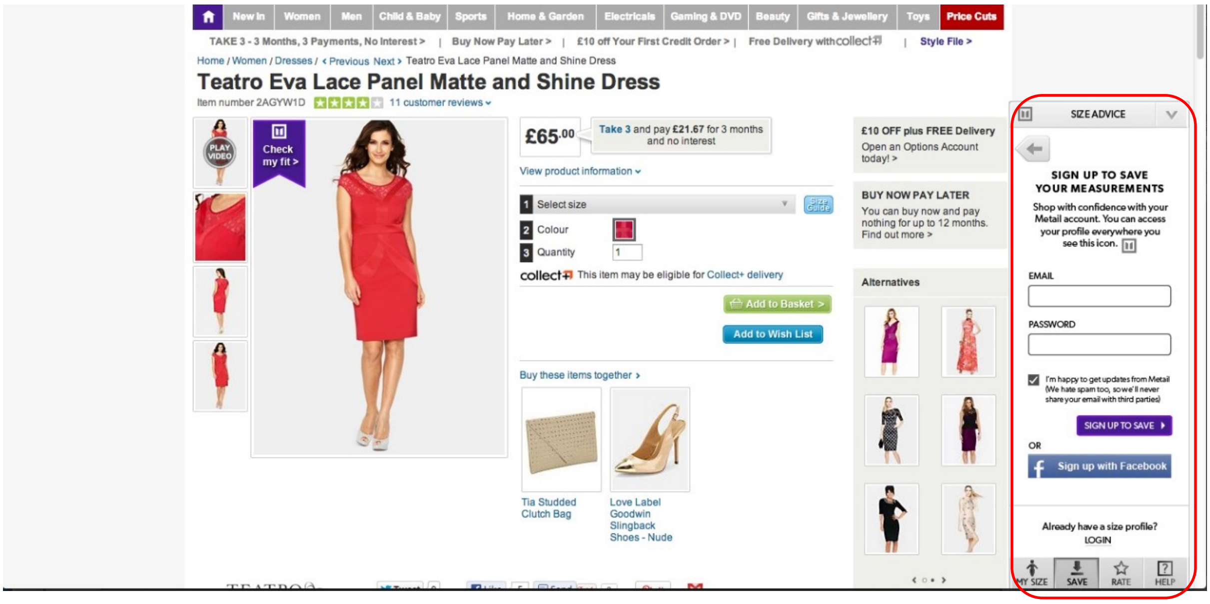
Metail f



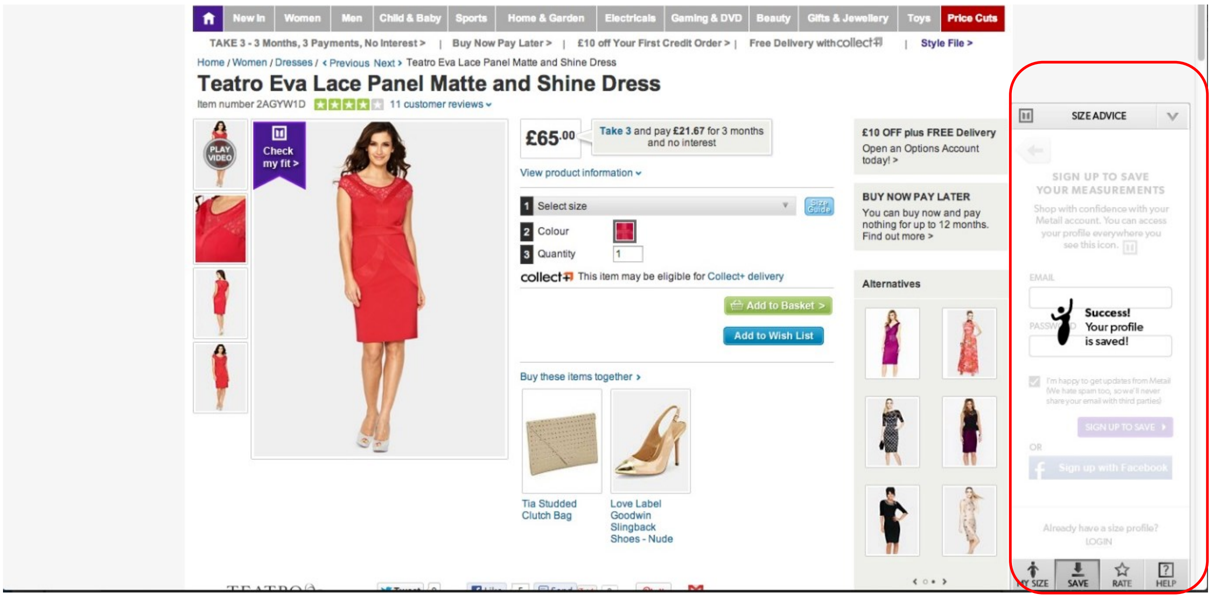
Metail g



Metail h



Metail i



Metail j

This information was send through to demonstrate how Metail operates. The company did not wish for feedback on the technology from the university as they already had bought into it and felt it fitted their purpose.

Paragraph 3

This person is the garment technologist from the company.

Paragraph 4

The company has referred to reduced measurements in all but one correspondence at this point 4 June 2013. Their initial aim is to link the scan data to the Metail technology which only requires four measurements. This indicates the scanner is perceived as a means to providing these measurements.

Paragraph 7

The company wishes get confirmation on the budget at this point. Indicating their requirements have been met so far and they know what they want from the scanner. At this point it should be mentioned that they have not commented on the development of size charts which was sent as a link to them in early May.

Paragraph 8

This leaves scope for further discussions and demonstrates the company is open to suggestions and recommendations. During face to face meetings it became apparent that the company had a general knowledge of what the scanner did (provide body measurements) how they did not consider further scanner applications. The team had made suggestions based on their own exploratory research (ie, shape calculation, size chart development, grades, appraisal of posture and body attributes).

Paragraph 10

Marketing terms. Virtual fitting room, mixing computing terms with familiar shopping terms. The company is linking itself to traditional practice and new technologies. By focussing on the garment fitting stage of the purchasing process they are signalling to the customer that they are proactive in providing well-fitting garments.

An online launch which requires the customer to measure themselves. Here the company is allowing the customer to engage in the process.

Interestingly they acknowledge Metail is not entirely perfect but do not elaborate further. Their interest is making the scan team familiar with metail so the scan team can facilitate an effective link between the scan data output and the Metail technology.

Metail a
They outline the potential process. Here it is clear how they wish to marry the scanner with the Metail technology.

Metail b
Personal sizing information will appear on the righthand side of the screen (see red shape). As we read left to right in the UK the eye would be drawn to that side of the screen once the customer has looked at the image and product details. Interestingly the sizing information is not centre screen. The product image and details fall within that area making the product still the main focus.

Metail c
Using the word confidence and titling the sizing information as 'your size profile' is intended to give assure the customer they will be getting the correct size for them. Asking the customer to save their size profile enables the company to keep the size data from which they can build a database of all of their customer's height, weight and bra size. At this point the company is reliant on the customer to know their correct size. The customers are encouraged to engage at this point.

Metail d
Metail will offer size advice based on height weight and bra size. The customer is offered an estimate size.

Metail e
Suggested fit is offered on bust waist and hips depending on type of garment selected eg loose fit for the waist on this dress. It also suggests a size code.

Metail f
It also offers estimated waist and hips but does allow for the measurements to be edited by the customer. Again customer engagement is encouraged. Using the words 'best results' indicates that if the customer wishes to input their own measurments the accuracy of the facility is improved. The estimates are based on averages within

Metail but the way this is set up it does recognise that not all their customers conform to averages.

Metail g

The customer is prompted to place their order into a basket once the continue button is pressed from the previous screen.

Metail h

The customer is reminded that they can shop with confidence. Interestingly women from this demographic are not confident purchasing online. They are encouraged to give contact details to be able to save their sizing information. This process replaces the size guide system but for customers to be able to give their bust waist and hip dimensions then some information on how to take the measurements and appropriate definitions would be useful here.

Metail i

Customer is given guidance on how to sign up though.

Metail j

A logo ‘punching the air’ and the words success and saved are all encouraging positive devices.

35.1.5 Correspondence five

Paragraph #	Scanning project for [redacted]	Main Themes	Associated words
	Scanning for [redacted] at Womenswear Weekly, 13-15 September, Event City (Trafford Park), 10:00-5:00pm.		
	We will need to cost in the packing, transport and unpacking of the body scanner so the event for us will be 12th-16th September for the scanning. We will need to cost in at least 2 days prior to this for development of the support resources and 5 days after for cleaning and data analysis.		
	Minutes 05 June 2013		
	Present at the meeting:		
	[redacted], [redacted]	3 Marketing personnel, two garment technologists present from the company.	
	Critical Measurements: inside leg - follows leg to floor. Bust girth (bust point, own bra), underbust girth, waist girth (41 from nape), full hip (61cm from nape), top hip (51 from nape), r side neck to bust point. Put together an MEP.	Scanner utilisation the company is requiring more explicit measurements at this stage. Some of the	Scanner utilisation – critical measurements, MEP, inside leg, under bust, bust girth, waist girth,

		measurement definitions appear to be used for garments ie waist girth 41 from nape	full hip, side neck to bust point.
	Height, weight, bra size, waist and hip.	Scanner utilisation required dimension output from the scanner	Scanner utilisation – height, weight, bra size, waist, hip
	Questions: we will ask for bra size. ([redacted] will develop customer questionnaire),	Engagement with the customer The company was willing to let the customer first determine what bra size they were	Engagement with the customer – ask, customer, questionnaire
	What will they take away, printout of measurements.	Scanner utilisation, Aims and achievements	Scanner utilisation – printout, measurements Aims and achievements – they will take way
	Check on whether the bra is fitted on properly. [redacted] internal QA team.	Fit	Fit – check, fitting, properly

	Fit clinic. Are they in the bra properly.		(2), internal QA team, fit clinic
	Scan Journey, curtained off area as private scan,	Marketing Privacy	Marketing – scan journey. Privacy – curtained off, private
	Explain the scan journey before customers go through. Customers will be forewarned. Photographs of the scan process.	Marketing Privacy	Marketing – scan journey, photographs, process Privacy – customers, forewarned
	14 people, 2 measurers, 2 techs, (staff).	Logistics	Logistics - staff
	Measure space requirements.	Logistics	Logistics - space
	Goodie bags. Inc print output, [redacted] brand.	Marketing	Marketing – goodie bags, brand
	FFIT shapes.	Research	Research - shapes
	Scans, we host and sell if required. Costings for this. Cost for the outputs. Powerpoint presentation about what has been learned from the project. Posture, proportion and shape. Ratios, bust to waist and drop value in cm.	Scanner utilisation Time and cost Aims and achievements	Scanner utilisation – posture, proportion, shape, ratios, drop values

			Time and cost – sell, cost, output Aims and achievements – power point presentation, learned from project
	list of shapes and research paper (lee *et al,* 2007).	Scanner utilisation	Scanner utilisation – list, shapes, research
	Visual summary of the pelvis area, pitch of pelvis.	Scanner utilisation	Scanner utilisation – visual, pelvis area, pitch of pelvis
	Quote, day staffing, 5 days of data analysis, [redacted] and techs. Extra outputs daily rate. How can we use data. Linked project with students.		
	Project meeting fortnightly. Fridays.		
	Estimated b,w,h from BMI. Can automate avatars, test against scan avatars.		
	TO DO: [send video of outputs. Contract and costing. Ratios for shapes and Lee paper]		

Themes	Count of main themes
Pink – Marketing	3

Yellow – Scanner utilisation	6
Green – Aims and achievements	2
Blue – Time and cost	1
Purple – Engagement with the customer	1
Red - Company research	0
Grey - Positive about technology	0
Cobalt – Fit	1
Olive - Privacy	2
Teal - Logistics	2

Metail not really discussed at this meeting. Garment tech spoke more and explored how the scanner can help with blocks. The company was happy to take suggestions from the scanning team regarding applications of the scan data.

Paragraph 17

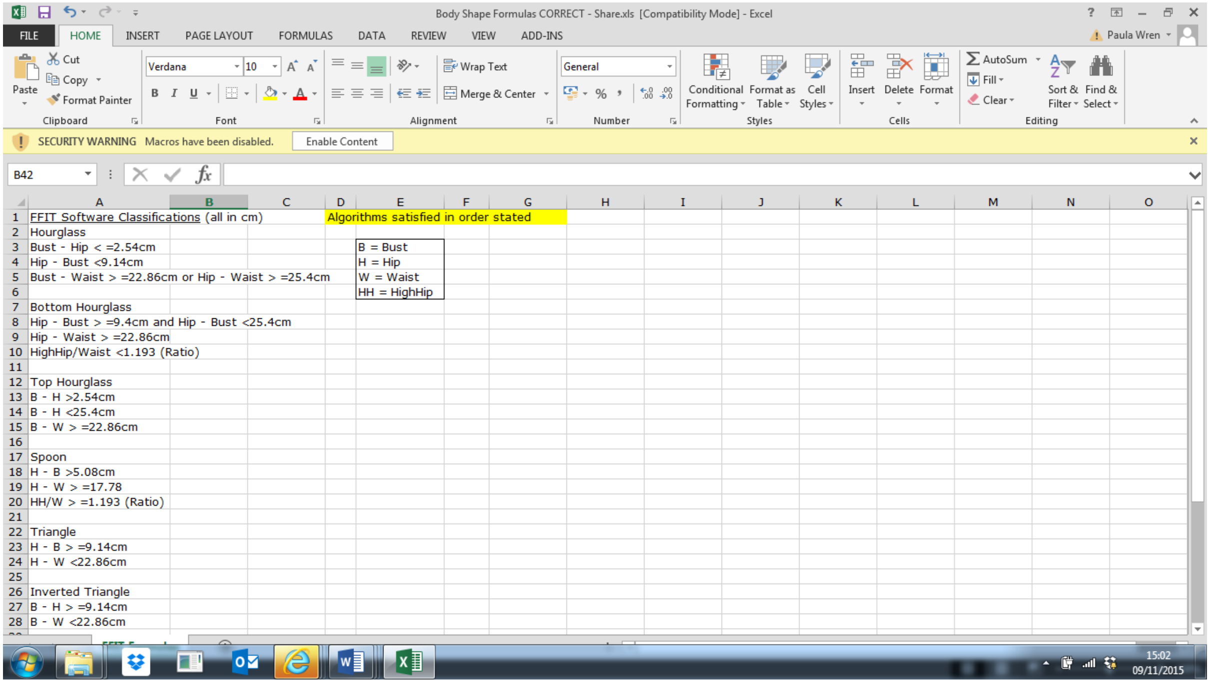
At this point height and bra size could not be calculated by the scanner. The company did not seem to grasp that the scanner was predominantly used to extract body dimensions and therefore did not output garment size codes.

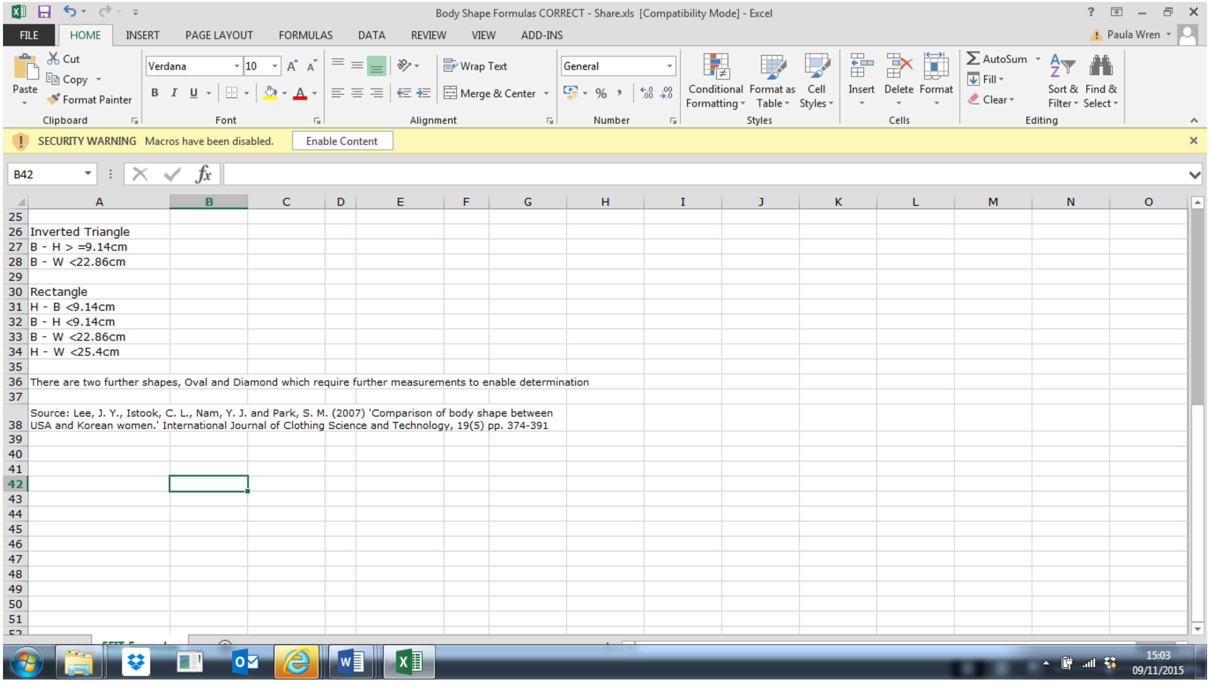
Paragraph 20
This was done in conjunction with scanning. The company had a bra fit expert whose knowledge they relied upon.

35.1.6 Correspondence six

Follow up to the 5 June meeting. Email sent by university scanning team

The shape calculation excel sheet was also sent to them in this email as they had showed interest in it during the meeting. They are beginning to open up to other applications that the scanner can provide. Predominant customer shape was something they found interesting. During the meeting of the 5th the garment tech did acknowledge that mature women often have a less defined waist due to weight gain and a thickening of the torso in that region. She mentioned the rectangular shape and said the block had been developed to reflect this.





1.	Hi [redacted]	Main themes	Associated words
2.	Please find attached details of the body shape classification formulas for [redacted].	**Communication**	**Communication** - details
3.	The link to the video explaining the scanner potential is: http://youtu.be/gZQOvpVEbsg	**Communication** **Scanner utilisation**	**Communication –** link, video, explaining **Scanner utilisation –** scanner potential
4.	Please let me know if there is anything further, you require. I am due to meet with our research support tomorrow and hope to have an outline costing to you within the next few days.	**Communication** **Time and cost**	**Communication –** please, me know, you require **Time and cost –** outline costing
5.	Best Regards		
[redacted]	[redacted]		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	1
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Olive - Privacy	

Teal - Logistics	
Navy - Guidance and confirmation	
Brown - Communication	3

Italics – represents the company's own words

Non-italics – represents the scan teams words

Anonymous font – field notes of conversations and actions from both parties

Paragraph 1
Garment tech from the company wanted to understand this.

Paragraph 4
We have not costed as yet even though the company is keen to know the budget.

35.1.7 Correspondence seven

Bra size and the Scanner

[redacted] email request some of the female members of the scan team to see if the scanner can calculate bra size.

Paragraph #	**Email (9 Aug 2013) from marketing department to the scan team regarding Bra size**	**Main themes**	**Associated words**
1.	*Hi Ladies*		
2.	*I just wanted to follow up on my question about bra size, you may have missed it amongst the many emails - is it possible to get a reading so we can tell customers their bra size? This is a really important measure in terms of measurements needed for Metail and we'd like to include this if possible. In order to give or find out bra size, we'd need to know the circumference in inches of the fullest part of the bust and the under bust. Do you measurements give these readings?*	**Scanner utilisation** **Aims and achievements** **Communication**	**Scanner utilisation** – reading, bra size, important measure. **Aims and achievements –** needed for Metail **Communication –** follow up, question, missed amongst many emails
3.	*Thanks*		
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted] *Brand Team*	[redacted]	
[redacted]	[redacted]		

Paragraph 1

The person from the company starts with a very relaxed greeting as she is addressing the female members of the scanning team.

It is evident at this point that the after the presentation of the scanner by the marketing team to the company that comments and suggestions were made regarding scanner output and linking to Metail. The scanning team told the company that the scanner gives body dimensions and this is apparent in the screen shots of scans that were sent via email. However, the company is now asking if the scanner can provide bra-sizing information as part of its output stating it is necessary for the link between the scanner and the Metail technology to be affective.

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	1

Green – Aims and achievements	1
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy (1st time mentioned)	
Brown - communication	1

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

Paragraph #	[redacted] reply: to emailed question of bra size calculation from the 5-15 August	Main themes	Associated words
1.	Hi [redacted]		
2.	Yes the scanner will give you bust (taken at the fullest part of the bust) and under bust which we have found is placed on the bra band at the bottom of the bra. It cannot, as far as I know, say you are a size 36B but it will give you the measurements in cm.	**Scanner Utilisation**	**Scanner Utilisation** – scanner, will fullest bust, under bust, cannot say size, measurements, cms.
3.	Just to bear in mind the scanner requires that the person wear a bra (for ethical reasons) so the type of bra may affect the measurement ie if it is very padded. The scanner cannot 'see' that the person is wearing a padded bra and will take the measurement over the surface of the bra cup so the bust reading maybe slightly more.	**Privacy** **Scanner accuracy**	**Privacy –** wear a bra, ethical reasons. **Scanner accuracy –** bra affect measurement, scanner cannot 'see' person wearing bra, padded bra, measurement over surface, bust

			reading slightly more.
4.	I normally scan the person in their own bra stating that they should wear their most comfortable and favourite one.	**Fit**	**Fit –** scan person own bra, wear most comfortable favourite one.
5.	I hope this helps, see you on the 20 Aug.		
6.	Take care [redacted]		
7.			
8.			
9.	[redacted]		
10.	Senior Lecturer		
11.			
12.	[redacted]		
13.	[redacted] reply:		
14.	*Thanks [redacted] that's good to know. I think we need to look at maybe having a conversion chart somewhere at the event so customers could find out their bra measurement. For the metail recommendation tool the person needs to enter their waist, hips and bra size but we know there are stats out there saying that over 50% of women are wearing the wrong size bra. It would be really useful if we could include this measurement on the print out but I think it's needed in inches.*	**Engagement with the customer** **Research** **Scanner utilisation** **Communication**	**Engagement with the customer –** conversion chart, customers find out their bra measurement **Research –** we know, stats, over 50% women wearing wrong size bra **Scanner utilisation –** useful, include, measurement, printout, inches **Communication** – good to know
15.	[redacted]		
16.	[redacted]		
17.	[redacted] *Brand Team*		
18.	[redacted]		
19.	[redacted] reply		
20.	Hi [redacted] A conversion chart would be great, we have one for height and weight as many people find the imperial system easier to understand for these	**Engagement with the customer** **Scanner utilisation**	**Engagement with the customer –** people, imperial system, easier,

	measures. The scanner can read in inches and has a facility to present this. The only thing with this (as far as I know) is that all the measurements would then be in inches. So I suppose the conversion chart would be quicker plus gives an opportunity to discuss bra type/size and any fitting issues if need be. Take care [redacted] [redacted] Senior Lecturer in Fashion Technology Manchester Metropolitan University Department of Clothing Design and Technology Room [redacted] Hollings Faculty		understand, opportunity, discuss, fitting issues **Scanner utilisation –** scanner, read inches, facility, present, all measurements in inches
21.	[redacted] reply:		
22.	*Hi [redacted]* *I've been thinking about the measurements and I think inches for all measurements would be ok in terms of the print output for participants but I'm not sure if this would be an issue for 'companies garment tech' for the data she requires.* *Thanks* [redacted] [redacted] *Brand Team* [redacted]	**Scanner utilisation**	**Scanner utilisation –** inches, all measurements, ok, printout, participants, not sure issue, (garment tech), data requires
23.	[redacted] *reply:*		
24.	*Hi [redacted],* *I hope you are well.* *I wanted to ask if it would be possible to add in a programme that would calculate a person's bra size from the measurements given in the scan for under bust and fullest part of the bust? I've included a video which details how the bra size is found, can you have a look and see if there would be any way of putting this into a formula and giving the participant their bra size please?* *Video link, let me know if you have any problems*	**Scanner utilisation** **Research** **communication**	**Scanner utilisation** – possible, add programme, calculate, person's bra size, measurements given, fullest part, under bust, putting into a formula, giving participant bra size

	accessing it - *http://vms.liveclicker.com/vms/asset.php?asset_id=1949185893* *Can you come back to me on this for our meeting on Tuesday please?* *Thanks* [redacted] [redacted] *Brand Team* [redacted]		**Research –** included video, details how bra size, found **Communication –** video link, let me know, problems, accessing, can you come back, meeting, please
25.	[redacted] reply:		
26.	Hi [redacted] I seem unable to access the video link you included, could you resend? I am sure we could put a chart together to enable customers to determine their bra size from the scan output, however it would be difficult to build this in to the current scan output. I will try and work out our options for next Tuesdays meeting. Regards [redacted]	**Communication** **Scanner utilisation**	**Communication** – unable to access, link, resend, try work out, options **Scanner utilisation** – chart difficult, to build in to current scan output
27.	[redacted] reply:		
28.	*Hi* [redacted]*,*		
29.			
30.	*Sorry about the link I thought there may be an issue, here's a link you shouldn't have a problem with - Here's the bra video: https://vimeo.com/69745394*	Communication	Communication – sorry, link, issue, shouldn't have problem
31.			
32.	*Thanks*		
33.	[redacted]		
34.	[redacted]		
35.	[redacted] *Brand Team*		
36.	[redacted]		

Themes	Count of main themes
Pink – Marketing	0
Yellow – Scanner utilisation	6

Green – Aims and achievements	0
Blue – Time and cost	0
Purple – Engagement with the customer	2
Red - Company research	1
Grey - Positive about technology	0
Cobalt – Fit	1
Olive - Privacy	1
Teal - Logistics	0
Navy – scanner accuracy	1
Brown - communication	4

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

This set of emails centres around the outputs of the scanner, and what it can provide for the general public and the technical team. The company wants the scanner to provide bra size and then during the course of correspondence they realise the team cannot programme the scanner to do this. Eventually they settle for a bra size chart to enable the customer to determine their size from the fullest bust and under bust measurements.

The person writing the emails has requests and is trying to understand scanning technology as they are using terms such as programming, calculating and output. There also appears to be communication difficulties as emails are lost or not acknowledged. The person writing the emails uses words and videos to communicate what they want.

Paragraph 22

The measurements need to be in two different formats for it to be useful to both the general public and the technical team. It is not clear to this person that the scanner can give data in both sets of measurements at different times to either the public or the tech team. This person does not fully understand the outputs of the scanner at this point.

35.1.8 Correspondence eight

Paragraph #		Main themes	Associated words
1.	Sent: 16 August 2013 17:05		
2.	To: [redacted]]		
3.	Cc: [redacted]		
4.	Attachments:		
5.	Hi [redacted]		
6.	There is no issue with underwear colour for the KX16 scanner. The older scanner required this, but the new one is fine with any colour.	**Scanner utilisation**	**Scanner utilisation –** no issue, underwear colour, KX16, older scanner required this, new one, fine
7.	I have been asked by our business development team to follow up about the contract for services. We require six students to support the event and cannot recruit them until we have the contract for services signed and returned. Please let me know, hopefully we can discuss on Tue.	**Communication** **Logistics**	**Communication –** asked business development, follow up, contract for services, until have the contract, cannot recruit **Logistics** – require six students, support event
8.	Best Regards		
9.	[redacted]		
10.	On 16 Aug 2013, at 16:11, "[redacted]> wrote:		
11.	*Hi [redacted],*		
12.	*One thing that I think we need to discuss on Tuesday is the need for wearing flesh coloured underwear in the scan. We are*	**Scanner utilisation**	**Scanner utilisation –** flesh colour

	concerned that women attending the event will not all be in flesh coloured underwear. How does this affect the scan output?		underwear, scan, concerned, women will not, effect scan output
13.	*Thanks*		
14.	[redacted]		
15.	[redacted]		
16.	[redacted] *Brand Team*		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	2
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	1
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	1

Italics – company's words

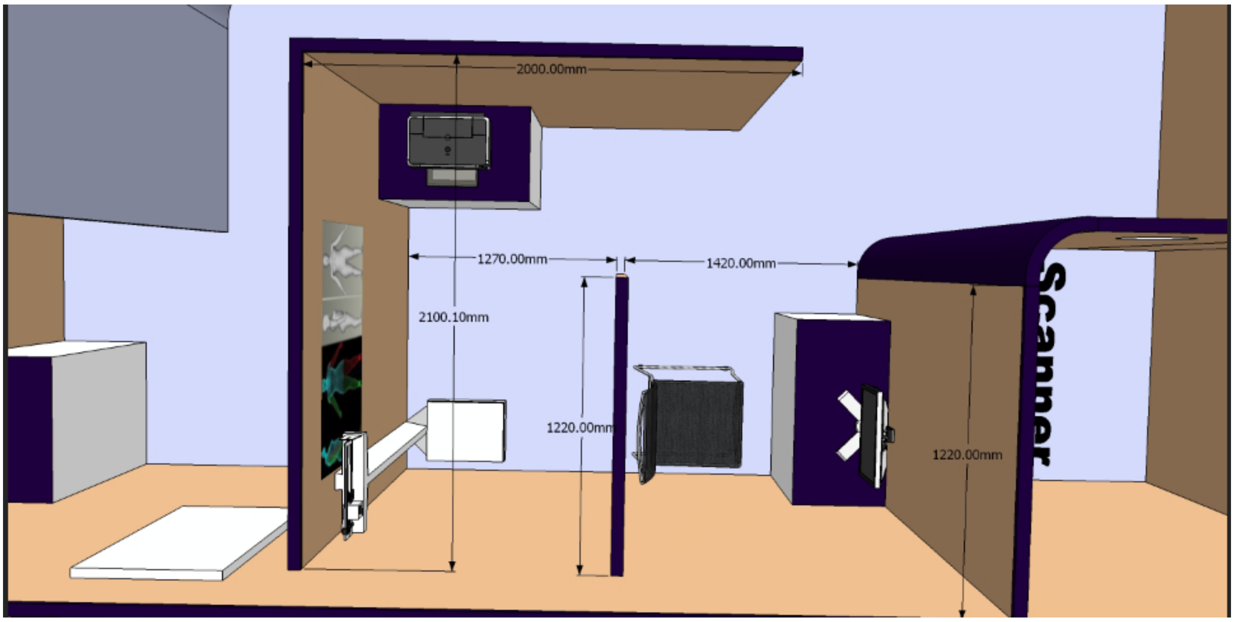
No italics – scan team's words

'Anonymous' font – field notes

35.1.9 Correspondence nine

The event set design

Paragraph #	Sent: 21 August 2013 09:22	**Main themes**	**Associated words**
	To: [redacted]		
	Cc: [redacted]		
	Attachments: [redacted] draft 8 measure room ~1.jpg (221 KB)		
	Hi [redacted]		
	Can you take a look at the attached drawing and let me know if the scale is ok for the measurement area please?	**Guidance and confirmation**	**Guidance and confirmation** – look drawing, let me know, scale ok
	I spoke to [redacted] *'set designer' and including hand grips inside the scanner will be fine, just let me know at what height you need them.*	**Logistics**	**Logistics** – handgrips, inside, fine, what height
	Also I mentioned that you wanted to set up the scanner on the 10th and Steve said that he would need to build 3 walls of the scanner first but could leave the door free for you to then set up. Will that be ok with you?	**Logistics** **Guidance and confirmation**	**Logistics –** set up scanner, build three walls, leave door free **Guidance and confirmation** – ok with you
	Thanks		
	[redacted]		
	[redacted]		
	[redacted] *Brand Team*		
	[redacted]		



Set image

There does not appear to be the dimensions of the scanner included in this drawing. Noting a wall has been put between the computer area and the measurement area for privacy. Something which is not done in the anthropometrics lab at MMU.

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	2
Navy – guidance and confirmation	2
Dk grey – scanner accuracy	
Brown - communication	

Italics – company's words

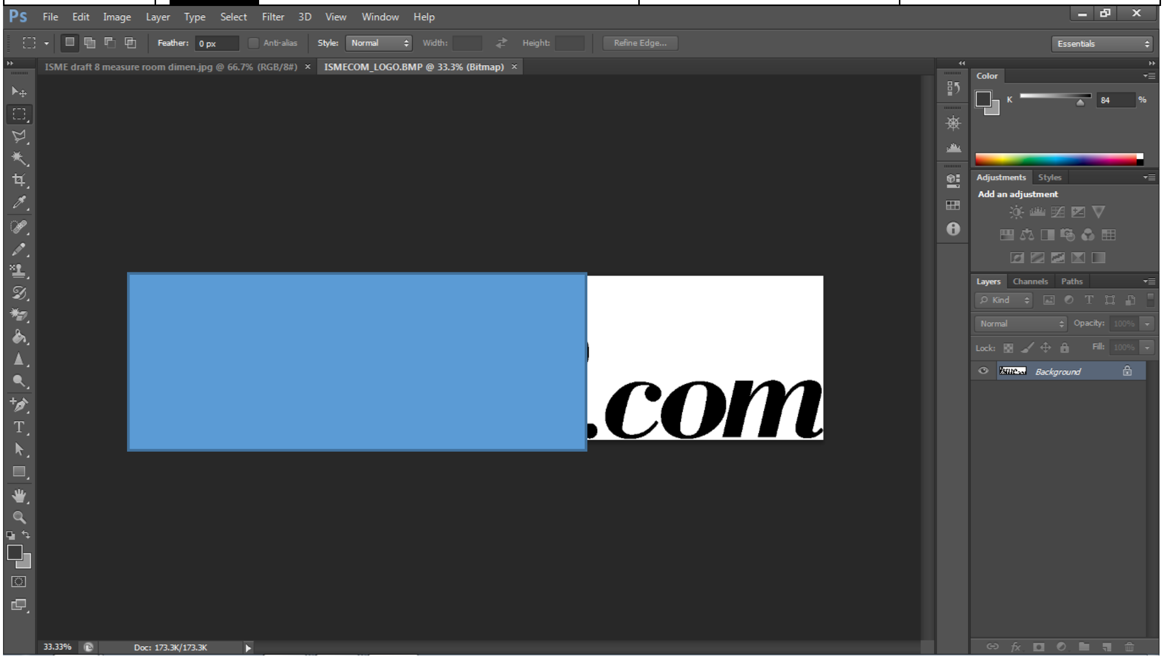
No italics – scan team's words

'Anonymous' font – field notes

35.1.10 Correspondence ten

Paragraph #	Sent: 27 August 2013 16:23	Main themes	Associated words
1.	*To:* [redacted]		
2.	*Cc:* [redacted]		
3.	*Attachments:* [redacted]*_LOGO.BMP (175 KB)*		
4.	*Hi* [redacted]*,*		
5.	*I hope you had a good weekend.*		
6.	*I've attached our logo in the format and size requested. Can you let me know if this is ok and then it would be great to get the amended scan output to show the team.*	**Marketing** **Seeking confirmation**	**Marketing –** logo, amended scan output, show team **Seeking confirmation –** let me know, ok
7.	*Can I check that you have everything that you requested in your email below? Let me know what you are waiting for and I will chase.*	**Communication**	**Communication –** let me know, waiting, I will chase
8.	*Thanks*		
9.	[redacted]		
10.	[redacted]		
11.	[redacted] *Brand Team*		
12.	[redacted]		
13.	From: [redacted]]		
14.	Sent: 20 August 2013 16:23		
15.	To: [redacted]		
16.	Cc: [redacted]		
17.	Subject: Documents from today		
18.	Hi [redacted]		
19.	I found today's meeting useful and hope we addressed some of the key questions.		
20.	Please find attached the document relating to the measurement definitions for the customer output, if these can be checked are okay I will set this up on the scanner customer output.	**Seeking confirmation** **Scanner utilisation**	**Seeking confirmation** – checked, are okay **Scanner utilisation –** measurement definitions for the customer output
21.	I have also attached the document with details on the bra calculation	**Scanner utilisation**	**Scanner utilisation –** bra calculation

	methods, it would be useful if these could be completed so we can look at how it may be possible to automate the bra size calculate if at all.		methods, we can look, maybe possible, automate bra size,
22.	Would it be possible to have the bust, waist and hip dimensions for the [redacted] range, this will allow us to investigate how we can look at shape and size in the report.	**Communication**	**Communication** – dimensions, investigate shape and size
23.	With regard to the PRINT HEADER: The custom logo to appear on the top of the scan output should be a .bmp file and be cropped to the dimensions 20x6.5cm.		
24.	Please let me know if you have any further questions		
25.	Regards		
26.	[redacted]		



Measurements Required By [redacted] to be output from the scanner	Definition	Method	
Height	The direct vertiacl height from the soles of the feet to the vertex of the head, taken with and anthropometer or stadiometer	Manually taken	Agreed
Weight	The value in KG or Lbs and ounces?	Manually taken	KG
Bust girth	The circumference of the bust taken horizontally at the greatest protrusion of either the left or right breast.	Scanner	Agreed
Under bust girth	The circumference of the body taken horizontally around the base of the bust	Scanner	Agreed
Waist Girth	The horizontal circumference of the body taken 41cm down from the CB neck point (nape)	Scanner	Agreed
Hip girth – lower	The horizontal circumference of the body taken 61cm down from the CB neck point (nape)	Scanner	Agreed

Themes	Count of main themes
Pink – Marketing	1
Yellow – Scanner utilisation	2
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	2
Dk grey – scanner accuracy	
Brown - communication	2

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

Paragraph 20

These measurement definitions were the definitions were used for bust, waist, hip and were more applicable to garment points of measure, ie waist is 41cm down from the side neck point.

Paragraph 22

The scan team is open exploring if the scanner can calculate bra size. However, they first need to be informed as to what bra size calculation method the company currently uses. The company did not initially ask for the scanner to calculate sizes but as the time passes they feel this is necessary to successfully link the scan data with the Metail technology.

35.1.11 Correspondence eleven

Paragraph #	Sent: 28 August 2013 13:31 To: [redacted] Attachments: [redacted] draft 8 image 2.jpg (497 K	Main themes	Associated words
1.	*Hi [redacted],*		
2.	*We'd like to show an example of the body scan image on the front of the body scan area. But we don't want to have any of the gridlines behind it and we'd like to show a nice body shape.*	**Marketing**	**Marketing** – example, body scan image, front body scan area, don't want grid lines, show a nice body shape.
3.	*Can you help at all? Or could you send a scan output in a format that we can play around with to remove areas that wouldn't be customer friendly in terms of marketing purposes.*	**Scanner utilisation** **Marketing**	**Scanner utilisation** – scan output, format play around with, remove areas, wouldn't be customer friendly **Marketing** – customer friendly, marketing purposes
4.	*We'd like to show the scan output in a similar way to the example on the attachment but we would only show one example.*		

5.	*Thanks*		
6.	[redacted]		
7.	[redacted]		
8.	[redacted] Brand Team		
9.	[redacted]		

Themes	Count of main themes
Pink – Marketing	2
Yellow – Scanner utilisation	1
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	

Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

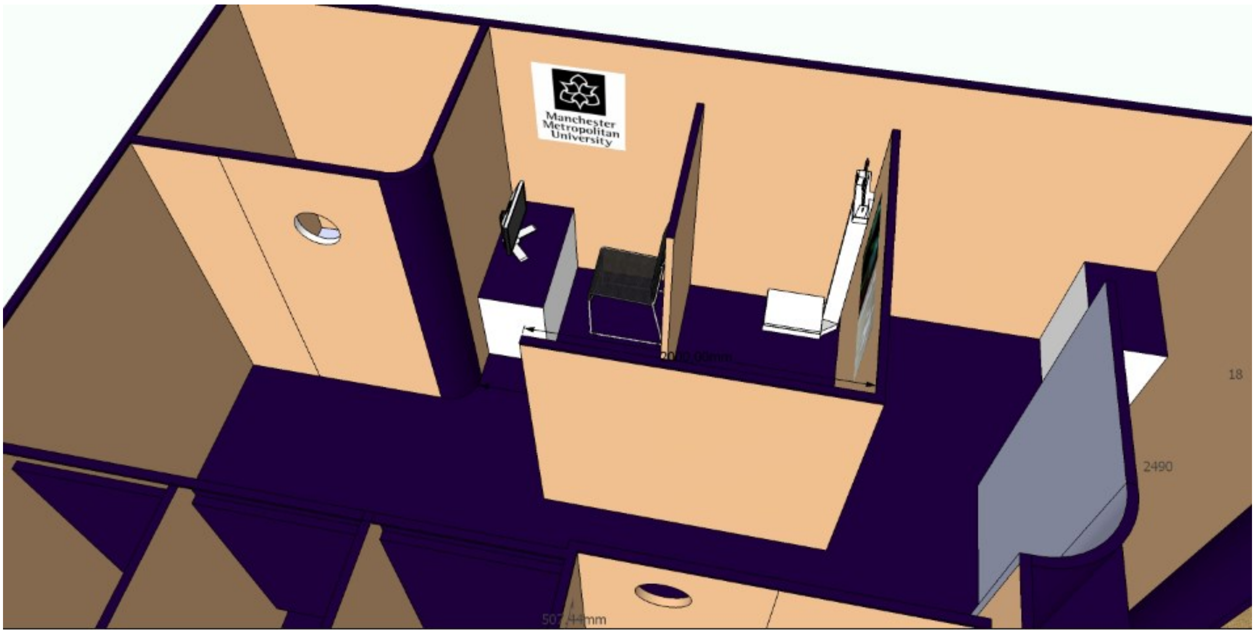
Paragraph 2

The image they are referring to is in the image below. The image is not a typical mature women's shape. The posture is very straight, the bottom is round and protrudes, the bust is also high and pert and the image has a clearly defined waist. The grey surface image looks smooth and resembles an avatar rather than an actual person.

35.1.12 Correspondence twelve

Paragraph #	Re: Woman's Weekly Live - Scan image	Main themes	Associated words
	[redacted]		
	Sent: 29 August 2013 11:55		
	To: [redacted]]		
	Cc: [redacted]		
	Attachments:		
1.	Hi [redacted]		
2.	I am sure this would be possible. I will try and send an image this evening. It is possible to get the image without the background, however, most images are taken as screenshots and this can make getting a suitable resolution difficult. I will also follow up with [redacted] on Monday.		

3.			
4.	Best Regards		
5.	[redacted]		
6.	[redacted]		
7.	Senior Lecturer in Fashion Technology		
8.	Hollings Faculty		
9.	Manchester Metropolitan University		
10.	M14 6HR		
11.	[redacted]		
12.			
13.	On 29 Aug 2013, at 11:48, "[redacted]> wrote:		
14.			
15.			
16.	Hi [redacted]		
17.	*Have you seen my email below, is this possible?*	**Communication**	**Communication –** have you seen my email?
18.	Kind regards		
19.	[redacted]		



Paragraph #	29 August 2013 16:55	Main themes	Associated words
20.	To: [redacted]		
21.	Cc: [redacted]		
22.	Attachments: [redacted] draft 9.1 image 3.jpg (282 KB)		
23.			
24.			
25.			
26.	*Hi,*		

27.	*Please see the attached body scan set design with the MMU logo placed in position. Please can you let me know if you are happy with this?*	**Marketing Guidance and confirmation**	**Marketing** – set design, logo **Guidance and confirmation** – are you happy?
28.	*Many thanks*		
29.	[redacted]		
30.	[redacted]		
31.			
32.	[redacted] Brand Team		
33.			
34.	[redacted]		
35.			
36.	From: [redacted]]		
37.	Sent: 29 August 2013 12:45		
38.	To: [redacted]		
39.	Cc: [redacted]		
40.	Subject: RE: Body Scan - MMU logo		
41.	Hi [redacted]		
42.			
43.	Please Find attacked		
44.	Thanks		
45.			
46.	[redacted]		
47.	From: [redacted]]		
48.	Sent: 29 August 2013 12:42		
49.	To: [redacted]		
50.	Cc: [redacted]		
51.	Subject: RE: Body Scan - MMU logo		
52.	*Hi,*		
53.	*Would it be possible to get the logo and guidelines today please? I need to send on to the set designer by the end of the day tomorrow.*	**Communication**	**Communication** – possible today please, I need to send by end of tomorrow.
54.	*The format needed is a Hi Res PDF, minimum 300dpi.*		
55.			
56.	*Thanks*		
57.	[redacted]		
58.			
59.	[redacted]		
60.			
61.	[redacted] Brand Team		
62.			
63.	0844 292 2378		
64.	From: [redacted]]		

65.	Sent: 29 August 2013 12:03		
66.	To: [redacted]		
67.	Cc: [redacted]		
68.	Subject: Re: Body Scan - MMU logo		
69.	Hi [redacted]		
70.	Yes, we would like our logo to appear on the scan booth. I have cc'd in our marketing team who will be able to provide high quality images, guidance on its use and answer any questions on the use of our logo.		
71.			
72.	Regards [redacted]		
73.	[redacted]		
74.	Senior Lecturer in Fashion Technology		
75.			
76.	Hollings Faculty		
77.			
78.	Manchester Metropolitan University		
79.			
80.	M14 6HR		
81.	[redacted]		
82.			
83.			
84.	On 28 Aug 2013, at 08:19, "[redacted]" <[redacted]> wrote:		
85.			
86.	*Hi [redacted],*		
87.	*Do we need to include your logo on the body scan booth? If yes, can you send me the logo and guidelines please?*		
88.	*Thanks*		
89.	[redacted]		
90.			
91.	[redacted]		
92.	[redacted] Brand Team		
93.	[redacted]		

Themes	Count of main themes
Pink – Marketing	1
Yellow – Scanner utilisation	
Green – Aims and achievements	

Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	1
Dk grey – scanner accuracy	
Brown - communication	2

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

This set of emails concern the marketing side of the event, particularly MMU's marketing information. The marking executive from the company is keen to get answers and information quickly whilst the team are slower to respond to the company's questions. The configuration of the scan set was developed in consultation with both the scanning team, the company and a third party set designer and this image is the final configuration of the set design. Interestingly MMU's logo is placed within the set so the customers would not know of MMU's collaboration until they arrive inside the set to be scanned. The set was developed primarily with customer privacy in mind with the flow of people through the set as the second consideration.

35.1.13 Correspondence thirteen

Paragraph #	Specific measurement for the scan printout	Main themes	Associated words
1.	Hi [redacted]		
2.	*Thank you for the images. That's a great help.*	**Communication**	**Communication** – thankyou, images, great help
3.	*On the scan output is it possible to remove the following?*	**Scanner Utilisation**	**Scanner Utilisation** – scan output, remove

		Guidance and confirmation	**Guidance and confirmation** – is it possible?
4.	· *The numbers before each of the descriptions e.g. [1]-Weight would become Weight?*		
5.			
6.	· *On Bust can you remove 'girth full'*		
7.			
8.	· *Remove 'full' after underbust, waist and hip*		
9.	*Also is it possible to include a space that would say 'Bra Size' for the runner to enter this manually?*	**Scanner Utilisation**	**Scanner Utilisation** – space, bra size, enter manually
10.	*With regards to the bra size measurement, can I ask if there is a big difference from the way we size a bra and the other measurement you have looked at? I'm surprised that we would measure this in a different way, I thought it would be a standard measurement. Obviously I'm not an expert!! But if there is a standard way, would this be the best to show on the comparison chart? Let me know what you think is best and I'll pick up with* [redacted]*.'garment tech'*	**Standardisation** **Guidance and confirmation**	**Standardisation** – bra size measurement difference, we size, other measurement you looked at, I thought it would be standard measurement, I am not expert, if there is a standard way, show on comparison chart **Guidance and confirmation** – what you think is best
11.	*Thanks*		
12.	[redacted]		
13.	[redacted]		
14.	[redacted] *Brand Team*		
15.	[redacted]		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	2
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	2
Dk grey – scanner accuracy	
Brown - communication	1
Forest - Standardisation	1

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

Paragrap 8

The company does not want to use the measurement coding system used by MMU. During a meeting they clarified that they want to make the names of the measurements both customer friendly and more similar to the names of measurements used by Metail.

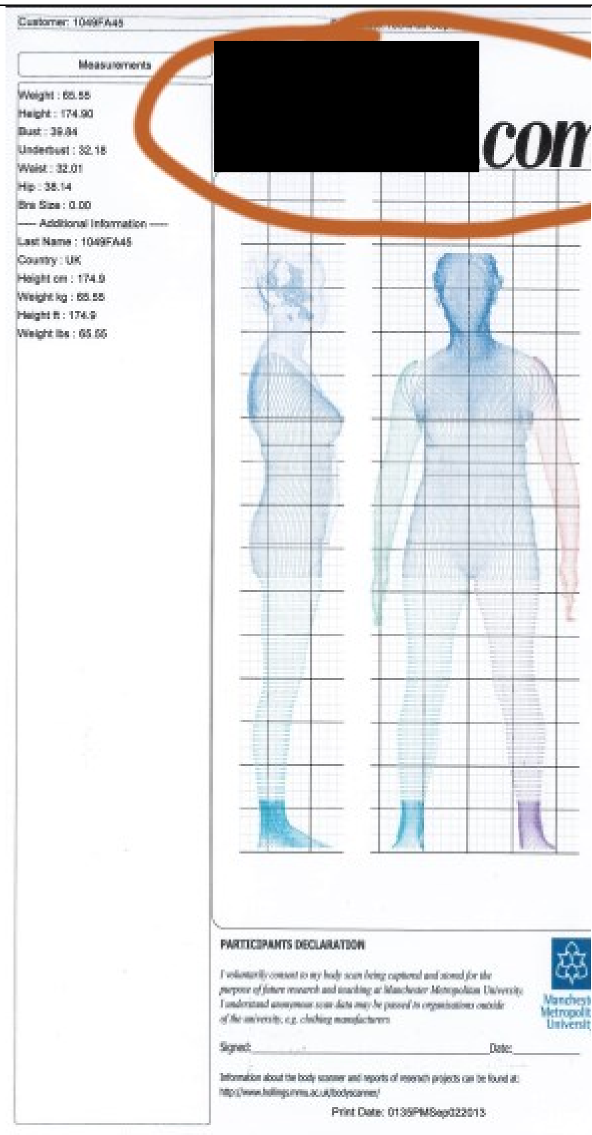
Paragraph 10
Here the company representative acknowledges that they are not an expert as they are involved in marketing. However they do go on to say they will liaise with the garment tech which implies they have similar expertise.

The company is still insistent on acquiring the bra size despite being informed that the scanner does not provide garment size information. They are open to different way of calculating bra size but intimate these methods need to be discussed with their own garment tech.

35.1.14 Correspondence fourteen

Paragraph #	**Meeting after event**	**Main themes**	**Associated words**
1.	[redacted]]		
2.			
3.	Sent: 04 September 2013 12:09		
4.	To: [redacted]		
5.	Attachments:		
6.			
7.	*Hi [redacted],*		
8.	*I hope you are both well.*		
9.			
10.	*First of all, can I just check on the bra conversion chart please?*	**Scanner utilisation**	**Scanner utilisation –** first check bra conversion chart
11.	*Secondly I'd like to get a date in the diary for us to talk about the data after the WW event, can you let me know when is a good time for you please?*	**Communication**	**Communication –** get a date for us to talk about the data after the event
12.			
13.	*Many thanks*		
14.	[redacted]		
15.			
16.	[redacted]		
17.			
18.	[redacted] *Brand Team*		
19.			
20.	[redacted]		
21.			
22.	***Scan output*** [redacted] **Sent:** *04 September 2013 15:44* **To:** [redacted] **Attachments:** *iMFD0046_02092013144444.jpg (519 KB); WWL_BODYSCAN_MEASUREMENTS_~1.PDF (93 KB)[Open as Web Page]*		
23.			
24.	*Hi* [redacted]		
25.	*Please find attached our version of the scan output for people who don't want to see their avatar. Can you let me know if you are happy with the MMU logo and the terms and conditions on there please?*	**Marketing** **Customer engagement** **Guidance and confirmation**	[redacted]

			[redacted]
26.	*And with regards to your scan output from the body scanner, can I ask you to take a look at the isme logo, it looks quite misshapen. Could we have it in our purple colour?*	**Marketing**	**Marketing** – look at logo, its misshapen, could we have our purple colour
27.			
28.			
29.			
30.	*Thanks*		
31.	[redacted]		
32.	[redacted]		
33.			
34.	[redacted] Brand Team		
35.			
36.	[redacted]		
37.			
38.	*From:* [redacted]		
39.	*Sent: 04 September 2013 13:44*		
40.	*To:* [redacted]		
41.	*Subject: Re: terms!!!*		
42.			
43.	*Hi* [redacted]		
44.	*Just thought – is this the final sheet that MMU are using?*		
45.	*They have scaled the ISME logo and stretched it vertically – ie looks pretty bad.*	**Marketing**	**Marketing –** scaled logo, stretched, looks bad
46.	*Can you ask if this can be fixed?*	**Communication**	**Communication** – you, ask, can, be fixed?

<table>
<tr><td>47.</td><td colspan="2">
Customer: 1049FA45
[redacted]com
Measurements
Weight : 65.55
Height : 174.90
Bust : 39.84
Underbust : 32.18
Waist : 32.01
Hip : 38.14
Bra Size : 0.00
---- Additional Information ----
Last Name : 1049FA45
Country : UK
Height cm : 174.9
Weight kg : 65.55
Height ft : 174.9
Weight lbs : 65.55
PARTICIPANTS DECLARATION
I voluntarily consent to my body scan being captured and stored for the purpose of future research and teaching at Manchester Metropolitan University. I understand anonymous scan data may be passed to organisations outside of the university, e.g. clothing manufacturers
Signed:______________________ Date:__________
Information about the body scanner and reports of research projects can be found at: http://www.hollings.mmu.ac.uk/bodyscanner/
Print Date: 0135PMSep022013</td><td></td></tr>
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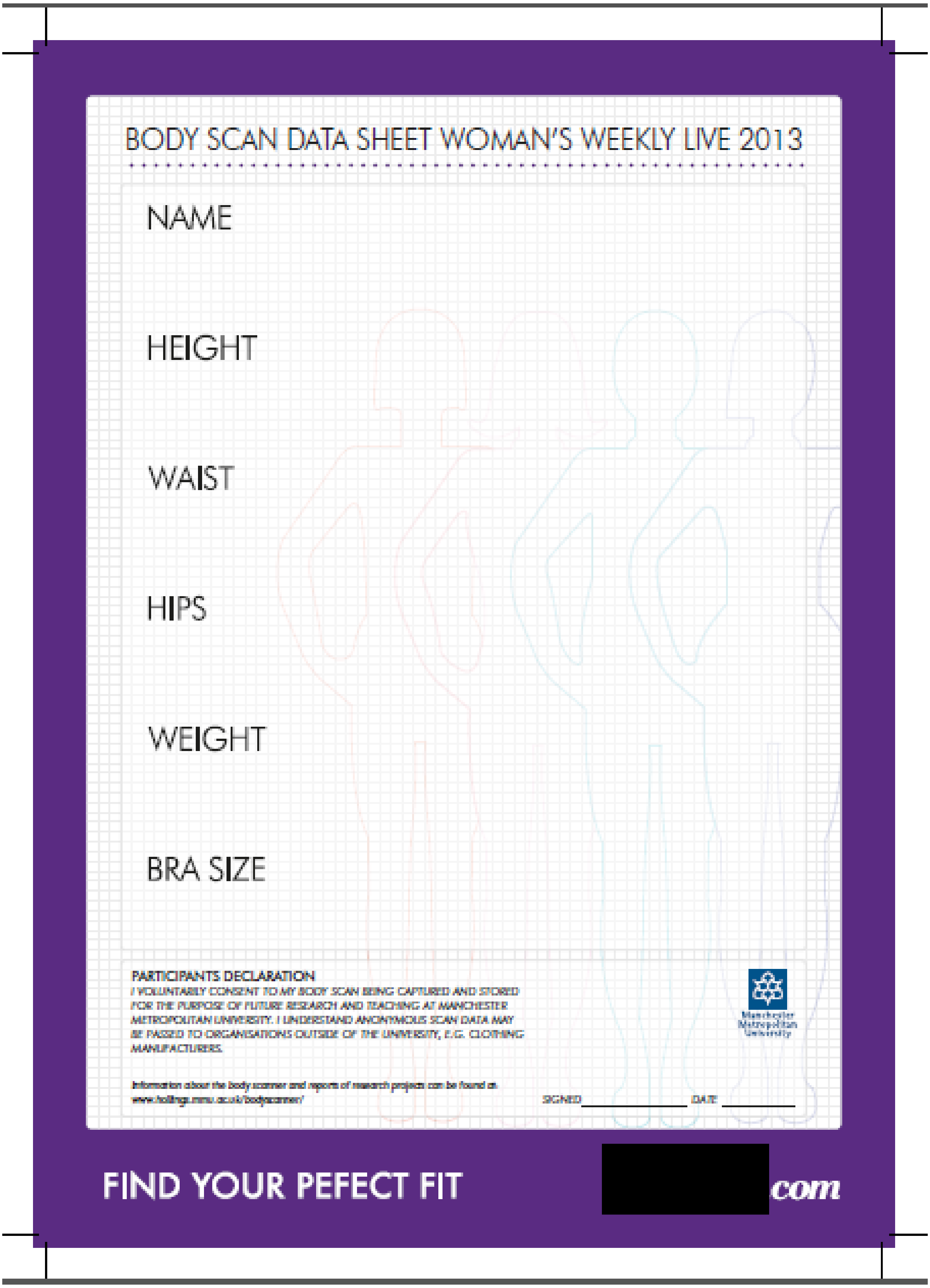
BODY SCAN DATA SHEET WOMAN'S WEEKLY LIVE 2013

NAME

HEIGHT

WAIST

HIPS

WEIGHT

BRA SIZE

PARTICIPANTS DECLARATION

I VOLUNTARILY CONSENT TO MY BODY SCAN BEING CAPTURED AND STORED FOR THE PURPOSE OF FUTURE RESEARCH AND TEACHING AT MANCHESTER METROPOLITAN UNIVERSITY. I UNDERSTAND ANONYMOUS SCAN DATA MAY BE PASSED TO ORGANISATIONS OUTSIDE OF THE UNIVERSITY, E.G. CLOTHING MANUFACTURERS.

Information about the body scanner and reports of research projects can be found at www.hollings.mmu.ac.uk/bodyscanner/

SIGNED ____________ DATE ________

FIND YOUR PEFECT FIT [redacted].com

Body scan data sheet

The body scan data sheet contains the relevant measurements for Metail alongside customer name. It has a grid back ground which mimics the grid background provided in the scanner printout. It also has a feint image of a females silhouette. The silhouette is stylised, hands on hips, with a slim hourglass shape.

Themes	Count of main themes
Pink – Marketing	3
Yellow – Scanner utilisation	1
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	1
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	1
Dk grey – scanner accuracy	
Brown - communication	2
Forest - Standardisation	

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

This set of emails arrived one after another from the company. It is getting closer to the event date and the tone of the emails, although congenial, is to the 'to the point' and the author of each email is organised and seeks to get clarification or problem solve quickly ie each request is numbered. The company marketing team dealing with the logo is frank and given the previously polite emails it is unclear if the company wanted MMU to see it or if it was a mistake which occurred in the rush of getting everything ready for the event.

35.1.15 Correspondence fifteen

Paragraph #	RE: Contract and invoice	Main themes	Associated words
1.	[redacted]]		
2.			
3.	Sent: 05 September 2013 17:07		
4.	[redacted]		
5.			
6.	Attachments:		
7.			
8.			
9.			
10.	*Hi* [redacted]		
11.			
12.	*Just to confirm for the larger sizes for the bra chart.*	**Communication**	**Communication** - confirm
13.			
14.	*The video we sent you went upto DD:*	**Communication**	**Communication** - video
15.	*So for the example sent:*		
16.	*Under bust was: 30 inches*		
17.			
18.	*So add 4 inches to get the back size = 34 inches (but if its an odd number you add 5 inches)*		
19.	*Then, when measure over bust:*		
20.	*If Same as back size (34) then = A cup*		
21.			
22.	*If 1 inch more (35) = B cup*		
23.			
24.	*If 2 inches more (36) = C cup*		
25.			
26.	*If 3 inches more (37) = D cup*		
27.			
28.	*If 4 inches more (38) = DD cup*		
29.			
30.	*If 5 inches more (39) = E cup*		
31.			
32.	*If 6 inches more (40) = F cup*		
33.			
34.	*If 7 inches more (41) = FF cup*		
35.			
36.	*If 8 inches more (42) = G cupThe only thing the team said was the above is just a guide, so when you do the Chart for us to put on the wall I think its worth using the word "guide" so its not definitive.*	**Communication**	**Communication** – you do the chart for us, though guide, not definitive

37.			
38.	*When do you think you could send through this wall chart?*	**Time and Cost**	**Time and Cost** – when could you?
39.			
40.			
41.			
42.	*Please could you confirm*	**Communication**	**Communication –** please confirm
43.	*Thanks in advance*		
44.	[redacted]		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	1
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Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	4
Forest - Standardisation	1

Italics are company's words

Non-italics are the scan team

Anonymous font are interpretive notes

This is a follow on email giving the calculations for the bra size. The company regard this portion of the work most important and are now getting two different people (both marketing and research and development) to chase for a bra sizing wall chart. The scanner is not discussed here and the email in essence is giving the bra size calculation and then chasing for a wall chart. The tone is pleasant but there is an undercurrent of urgency as the words confirm are used twice as well as an appeal for timings. It is getting nearer to the event and the company want to ensure the scan team have things in hand.

Paragraph 12

Here the company rep explains how they calculate bra size. The results of this provide standardised sizing.

Paragraph 14

They refer to a video which was shared on Dropbox. This was send in tandem with this email.

Paragraph 18

A simple formula which works for mass-produced sizing in bras.

Paragraph 36

Although the calculation has originated with the company they wish the scan team to use the info to present a wall chart. It is unclear why if they already have the calculation why they wish this. One explanation is because the scanner area is viewed as MMU's area and therefore the wall chart needs to be developed by the scan team using the company's methods.

35.1.16 Correspondence sixteen

Paragraph #	Contract and invoice	Main themes	Associated words
1.	Re: Contract and invoice [redacted]		
2.	Sent: 05 September 2013 10:37 To: [redacted]] Cc: [redacted] Attachments:		
3.	Hi [redacted]		
4.	Apologies for not getting back to you. We still do not have details of the direct inch	**Communication**	**Communication –** apologies, we do not have details,

	differences between the bust and underbust for determining the cup size for sizes above C cup. Until I have this we cannot develop the chart.		until I have this we cannot develop
5.			
6.	The non image printout looks fine, The document is a pdf, will this be in a format we can directly type into on the PC to or is it envisaged we we write the data in by hand? I will look again at the file for the [redacted] branding of the scan printout, the colour should be the same as it is set in the .bmp file, who can I liaise with directly in this?	**Marketing** **Communication**	**Marketing -** file for branding **Communication –** liaise directly with?
7.			
8.	We are still on course in terms of our preparations, I am at a conference today and tomorrow, but feel free to call me between 13:15 and 13:45 on [redacted], if there is anything you want to discuss		
9.	Regards [redacted]		
10.	[redacted] Senior Lecturer in Fashion Technology Hollings Faculty Manchester Metropolitan University M14 6HR		
11.			
12.	RE: Contract and invoice [redacted]]		
13.			
14.	*Hi [redacted],*		
15.	*Thanks you for getting back to me. I've just chased for the bra sizes, I'm sorry this hasn't been sent, I thought you had everything.*	**Communication**	**Communication –** Thanks getting back to me, I have been chasing, I am sorry this hasn't been sent, I thought you had everything
16.	*For the document we envisaged this being written in by hand on the off chance someone didn't want to see their scan output.*	**Customer engagement**	**Customer engagement** – off chance someone didn't want to see their scan output
17.			
18.	*Thanks* [redacted]		

19.	[redacted]		
20.	[redacted] Brand Team		
21.			
22.	[redacted]		
23.			
24.			
25.	[redacted]]		
26.	This message was sent with High importance.		
27.	Sent: 05 September 2013 10:01		
28.	To: [redacted]		
29.	Cc: [redacted]		
30.	Attachments:		
31.			
32.			
33.	*Hi [redacted],*		
34.	*Do you have an update on the contract and invoice please? I'm getting very nervous that the event is next week and I haven't heard anything from anyone.*	**Communication**	**Communication –** I'm very nervous, I haven't heard anything from anyone
35.	[redacted]*, could you please respond to my emails regarding the bra conversion chart. Are you around today to talk about the event?*	**Communication**	**Communication –** please respond to my emails, are you about today to talk about the event?
36.			
37.	*Many thanks*		
38.			
39.	[redacted]		
40.			
41.	[redacted]		
42.			
43.	[redacted] *Brand Team*		
44.			
45.	[redacted]		

Themes	Count of main themes
Pink – Marketing	1
Yellow – Scanner utilisation	

Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	1
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	5
Forest - Standardisation	

This set of emails discuss the final preparations before the event. The emails from the company sound anxious and emails are sent in a flurry from the company as they seek quick responses. The scan team did not have all the information with which to create a bra size chart. This information was supposed to come from the company's garment tech but was not sent on.

At this point many people are involved (both the company and the scan team) and information is going astray. Communication has broken down somewhat. The company do not seem concerned with the body scanner being ready. They feel this is the responsibility of the scan team and therefore are not concerned. Their main concern is the bra size chart which was not what they originally came to the scan team for. Nonetheless, they are determined they need the bra size chart as one of their primary objectives is to use Metail.

Paragraph 6

This phrase suggests that more direct communication with the pertinent personnel will help fix this situation. Is indirect communication delaying preparations?

Paragraph 8

This statement confirms that the scan team are organised and ready for the event. It is meant to reassure as the previous emails from the company sounded anxious.

Paragraph 15

There is a level of apology in this paragraph. The person sounds relieved to hear form the scan team and surprised that they did not receive everything they needed so late in the day.

Paragraph 16

The company is preparing for individuals who will not be happy looking at their scan images. They are trying to think and plan ahead.

Paragraph 34

This company individual is worried. They appear to be the sole point of contact for the company and the person whom everyone within the company asks to relay information.

35.1.17 Correspondence seventeen

Paragraph #	Contract and invoice	Main theme	Associated words
	[redacted]		
	09 September 2013 09:07		
	This message was sent with High importance.		
	Sent: 09 September 2013 09:07 To: [redacted]		
	Hi [redacted]		
	I hope you had a good weekend. I just wanted to get an update on the bra conversion chart. [redacted] sent over the measurements on Thursday.	**Time and Cost**	**Time and cost–** get an update
	Also, can you confirm when you will be arriving at EventCity to start the build of the scanner?	**Communication**	**Communication –** confirm, when, arriving
	Kind regards [redacted] Brand Team [redacted]		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	1
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	1
Forest - Standardisation	

Italics are the company's words

Non-italics are scan team

Anonymous font are interpretations

This email followed up the bra calculation email. The company are keen to get the bra chart completed as this is the first thing mentioned. The bra chart appears to be priority over when the scanner will be delivered and built. Again the email has an urgent tone (the email is marked high importance) with the company rep chasing confirmation of each question.

35.1.18 Correspondence eighteen

Paragraph #	Bra size calculation guidance sheet	Main themes	Associated words
1.	[redacted] has shared 'Guidance sheet for calculation of bra size at [redacted] event.docx' with you using [redacted]		
2.	[redacted]		
3.	Sent: 10 September 2013 17:38		
4.	To: [redacted]		
5.	Attachments:		
6.	Hi [redacted]		
7.	Please find the link to the bra calculation document below, I had put it in an obscure location, Apologies	**Communication**	**Communication –** find link, I put it in obscure location, aoplogies
8.	([redacted] it is in the [redacted] folder on [redacted], in the folder called [redacted] scan data, the logo is also there)		
9.	See you Thu		
10.	[redacted]		
11.	Here's a link to "Guidance sheet for calculation of bra size at [redacted] event.docx" in my [redacted]		
12.	https://[redacted]/s/v3qv5hi0a40k4qi/Guidance%20sheet%20for%20calculation%20of%20bra%20size%20at%20[redacted]%20event.docx		
13.	*Hi [redacted],*		

14.	*Thanks for this but it says its missing information at the bottom of the page, is this right?*	**Communication**	**Communication –** thanks, but missing information, is this right?
15.	*Great, I look forward to seeing you tomorrow.*		
16.	*thanks*		
17.	[redacted]		
18.	[redacted]		
19.	[redacted] *Brand Team*		
20.	[redacted]		
21.	From: [redacted]]		
22.	Sent: 10 September 2013 16:53		
23.	[redacted]		
24.	[redacted]		
25.	Subject: RE: Bra Conversion		
26.	Hi [redacted]		
27.	Please see attachment for the bra conversion information. Our students have been briefed on this chart yesterday.	**Communication**	**Communication –** see attachment bra chart, our students been briefed on chart
28.			
29.	[redacted] and myself will be down tomorrow to wire up the computers and to collect the exhibitor passes for our students and ourselves. [redacted] has not confirmed with myself the exact time but I would expect he would want to		

	organise it sometime in the morning. Is that okay [redacted]?		
30.	Take care		
31.	[redacted]		
32.	[redacted]		
33.	Senior Lecturer in Fashion Technology		
34.	Manchester Metropolitan University		
35.	***Bra Conversion***		
36.	[redacted]*]*		
37.	*You replied on 10/09/2013 16:53.*		
38.	*Sent: 10 September 2013 15:29*		
39.	*To:* [redacted]		
40.	*Attachments:*		
41.	*Hi* [redacted]		
42.	*Would it be possible to see an example of the bra chart, just to reassure the team that we have this please?*	**commun ication**	**Communication** – see chart, reassure the team
43.	*Will anyone from your team be there tomorrow?*		
44.	*many thanks*		
45.	[redacted]		
46.	[redacted]		
47.	[redacted] *Brand Team*		
48.	[redacted]		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	

Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	3
Forest - Standardisation	

Italics are the company's words

Non-italics are scan team

Anonymous font are notes

In this email conversation, the company's marketing representative is still enquiring about the bra calculation chart. As mentioned previously, knowing the bra size is integral to using the Metail technology and so this is why the company is so keen to finalise how to calculate the bra size using scan measurements.

Communication at this point is daily between the scan team and the company via email however there appears to be issues over the correct information being sent through. It appears that the wrong bra sizing document was sent as an attachment by one member of the scan team and another team member corrects this error by apologising and sending link to the correct document.

At this point in the case study documents are being sent in two ways via a secure cloud file sharing facility or by attaching to an email. It would have been perhaps helpful if one method of sending documents could have been agreed up on.

Paragraph 14

This was put together before we had there bra calculation

35.1.19 <u>Correspondence nineteen</u>

Paragraph #	Email correspondence prior to the event sent by the head of research and development for the company	Main themes	Associated words
1.	***Briefing Document for Women's Weekly Live - please read ahead of coming to the event.*** [redacted] *You forwarded this message on 14/10/2015 19:22.* ***Sent:*** *10 September 2013 15:46* [redacted] ***Attachments:*** *briefing doc for staff @ WWL.doc (40 KB)[Open as Web Page]* *Dear all,* *We're getting very excited about Women's Weekly Live and are really pleased you're all coming along to help out (thank you in advance!)* *Attached is a briefing document for each of you. Please could you all take the time to read through this. A lot of planning has gone into the event (as you've all been part of) and we're really keen to get the most out of the event in terms of delivering the key messages to consumers / getting as many people through the scanner / using the "check my size" tool and going on to order both fashion and home product!* ***Please can you meet us @ 9am in the pop-up shop each morning to run through the brief and go through who will be manning each area. Or if you're just coming for the afternoon, please find myself or [redacted] when you arrive to go through the brief / where you're needed / key messages etc.***		

	[redacted] – please can you forward this to all of your team who are coming to the event *[redacted] – same – please could you make sure everyone who is coming gets this email* *If I've missed anyone off who you know is coming – apologies and please can you forward this onto them,* *Thanks v much* [redacted]		
2.	*Content of the attachment:*		
3.	***<u>Women's Weekly Live</u>***		
4.	***<u>Key Objective</u>***		
5.	*To communicate that* [redacted] ***COMPANY NAME fits you perfectly'***		Strapline?
6.	*The body scanner and "check my fit" tool are all part of the overall positioning of* [redacted] *as "the perfect fit".*	**Marketing**	**Marketing –** body scanner, check my fit tool, perfect fit tool,
[redacted]	[redacted] *is one of the key brands sold under* [redacted] *and is what we will focus on during the event. This collection is built to fit you perfectly with 5 key features to flatter:*		
9.	*More garments with sleeves*		
10.	*On-the-knee skirt lengths to flatter legs*		
11.	*Secret panels to slim and support*		
12.	*Repositioned bust and necklines for better shape*		
13.	*Enhanced waistlines to fit your proportions*		
14.			
15.	*Where possible, please stress these benefits of the range.*		
16.	***<u>Confident Curves</u>***		
17.	*During the event we are doing 2 "fit" demonstrations featuring 2 items from our confident curves range. The key feature of both of these products is a hidden support panel that pulls you in and smooths lines / bulges and gives you the confidence to wear figure hugging styles.*		
18.	***<u>The Body Scanner</u>***		
19.	*We want to encourage as many people as possible to go through the body scanner – it just takes 10 minutes from start to finish. The benefits to the consumer are:*	**Aims and achievements**	**Aims and achievements –** want encourage as many people,

			through the body scanner
20.	*They will get a completely accurate read of their vital statistics (bra size, weight, height, waist and hips) plus a visual representation of their body (optional)*	**Scanner utilisation** **Engagement with the customer**	**Scanner utilisation** – completely accurate read of vital statistics, visual representation of their body **Engagement with the customer –** visual, optional
21.	*These can then be inputted into our "check my size" tool, so each consumer can be 100% confident that they're ordering the right size*	**Aims and achievements** **Positive about technology**	**Aims and achievements –** inputted into our check my size tool **Positive about technology** – consumer, 100% confident, ordering right size
22.	*Everybody who goes through the body scanner gets a great goody bag! (including bath relaxer, face serum, scarf, cuticle oil, chocolates and much more!)*	**Engagement with the customer**	**Engagement with the customer – everybody**, through the body scanner, gets a goody bag
23.	*They are helping us make sure that our range continues to fit today's body shapes*	**Engagement with the customer**	**Engagement with the customer –** they are helping us, range continues to fit today's body shapes
24.	***"Check my size" Tool***	**Marketing**	**Marketing –** size tool

25.	*After each consumer goes through the body scanner, the runner who accompanies them through the consultation, then hands them over to someone in the "pop-up shop" who will then show them how to use our brand new "check my size" tool - a size advice tool that helps you order the right size first time – to help you know every* [redacted] *piece fits before you order – so no more guessing or having to order items in two sizes! We will be completing a questionnaire for each consumer. Most of this is completed before the scan (and includes information about where the consumer normally shops and what size they normally order), then the member of staff who helps them use the "check my size" tool, will then record on the questionnaire what size is being recommended by our site (so we can analyse post the event how many people were ordering the incorrect size prior to using our new tool).*	**Engagement with the customer** **Marketing** **Aims and achievements**	**Engagement with the customer** – each consumer, through body scanner, runner accompanies them through consultation, hands them over, show them how to use, check my size tool, we will be completing a questionnaire for each consumer, before scan **Marketing** – size device tool, help order the right size, no more guessing **Aims and achievements –** check my size tool will record on questionnaire what size, recommended by our site, analyse post event how many ordering incorrect size prior to new tool
26.	*Also in our pop-up shop, once they've tried the perfect fit tool, we have on display all the clothes they've seen on the catwalk and more. A key objective of the show is to get consumers to order product! and so, if any consumer has seen any item on the catwalk that they like and they can't find it in the literature – please help them find the right item number – maximising sales and generating new customers is key.*	**Positive about technology** **Aims and achievements**	**Positive about technology** – the perfect fit tool **Aims and achievements –** maximising sales, generating new customers is key

27.	*We will be giving everyone an* [redacted] *branded badge to put on so that customers can find* [redacted] *representatives easily. Please try and answer any questions you can or find someone else in the team who might have the answer if you don't know it.*	**Engagement with the customer**	**Engagement with the customer** – try answer questions
28.	*Thanks for your help.*		
29.	***<u>Appendix</u>***		
30.	*<u>Confident curves leggings</u>*		
31.	*Have a deep re-enforced panel at the waist to give support / smooth lines and bulges in tummy area*		
32.	*Made from a heavier weight fabric than most other leggings:*		
33.	*so they're not see through (ie you can't see underwear!)*		
34.	*to give support*		
35.	*to minimise wrinkling on the knees!*		
36.	*Come in black, brown, grey, navy and brand new for this season – animal print!*		
37.	*Come in both standard and petite (not many competitors do petite and the advantage is they are slightly shorter in both the body and the leg)*		
38.	*Get what you pay for! They're slightly more expensive than some other leggings (£16.00) but the reviews and sales speak for themselves:*		
39.	*45,000 pairs sold in the last year*		
40.	*Over 600 fabulous reviews – here's a quote from Lindsay – one of our consumers:*		
41.	*"I wear these leggings all the time. They are the best ones I've ever bought. Thick enough so you can't see your knickers, perfect length. They come up over your tummy and are nice and tight so give great support. They're smooth and stay in*		

	place, you'll not need to pull them up once or fix a wrinkle at the knee. You will not regret buying them!!"		
42.	*We couldn't have put it better ourselves!!*		
43.	*<u>Confident Curves Dress (3EYKY)</u>*		
44.	*The killer feature! – secret-support / built-in undergarment*		
45.	*Gives you the confidence to wear a pencil dress in a stretch fabic which might otherwise show lumps / bumps / undergarments!*		
46.	*Really pulls you in (just like support underwear)*		
47.	*Giving you support and confidence (the confident curve!)*		
48.	*¾ length sleeve – a key style feature for this season, but also a perfect cover up area for the top of the arms – an area some women like to conceal*		
49.	*Nice sweetheart neck – but with mesh cover above – giving you the best of both worlds – a very flattering neckline, but still keeping cleavage and lower neck area subtley covered.*		

Themes	Count of main themes
Pink – Marketing	3
Yellow – Scanner utilisation	1
Green – Aims and achievements	4
Blue – Time and cost	
Purple – Engagement with the customer	4
Red - Company research	

Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	
Forest - Standardisation (Theme begins in correspondence 15)	

Italics are the company's words

Non-italics are scan team

Anonymous font are notes

Paragraph 6

The company calls the Metail technology 'Check my fit

Paragraph 13

Sleeves to cover arms, skirt lengths to knee, panelling in tummy and bottom area to smooth and lift, bust and necklines repositioned, waist lines in line with correct body proportions.

The waist positioning not discussed. When waist is mentioned it is discussed in terms of flattening the abdomen region and ensuring not underwear is visible.

Paragraph 16

This suggests they think all mature women will be curvaceous.

Paragraph 25

This suggests the consumer does not get to fill in the questionnaire by themselves.

Paragraph 30

The following list of garment descriptions demonstrate that the company is aware of body shape change in older women. They attempt to use the garments as a body shape correction or enhancement tool. The language used is descriptive and contains marketing soundbites

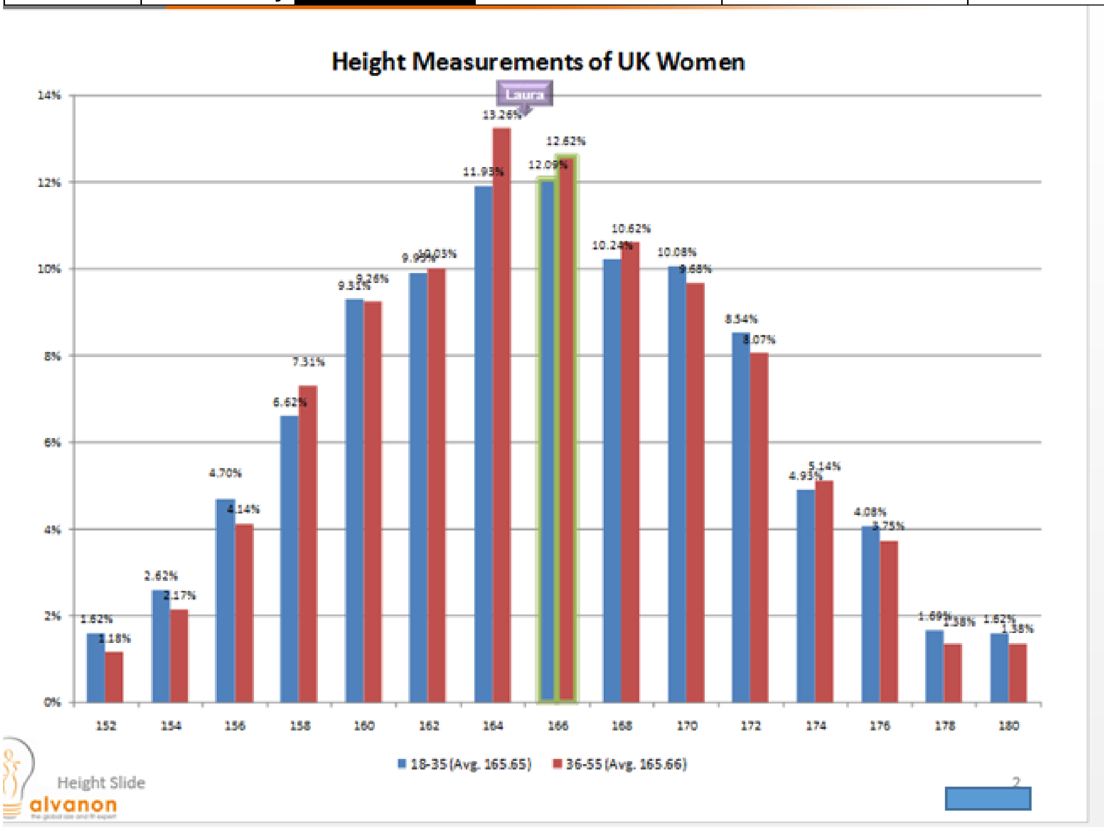
35.1.20 Correspondence twenty

Paragraph #	Meeting for results of body scanner analysis	Main themes	Associated words
1.	[redacted]		
2.	This message was sent with High importance.You replied on 20/09/2013 07:00.		
3.	Sent: 19 September 2013 17:29		
4.	To: [redacted]		
5.	Attachments:		
6.	*Hi both*		
7.	*Hope you've recovered from Women's Weekly Live!*		
8.	*Its been a mad week getting back on track this end, and* [redacted] *is now away for 2 weeks so could we arrange for the debrief to be either before2pm on Tues 8th Oct or anytime on Weds 9th Oct.*		
9.	*If its Weds we can come to you but if its Tuesday, it will need to be here.*		
10.	*Please can you let me know which suits.*		
11.	*I'll send the list of what we'd like included in the analysis by Monday of next week (22nd Sep),*	**Aims and achievements**	**Aims and achievements** – list, included, analysis
12.	*Thanks in advance*		
13.	[redacted]		
14.	Re: Meeting for results of body scanner analysis		
15.	[redacted]		
16.	Sent: 20 September 2013 07:00		
17.	To: [redacted]		
18.	Cc: [redacted]		
19.	Attachments:		
20.	Hi [redacted]		
21.	I am fully recovered now, thank you for asking. What a fabulous show!		
22.	I teach both days so I will struggle to get to Skyways on the Tuesday. Wednesday I am free between 10:30-12:00 or any time after 3:00.		
23.	Let me know if any of these times are useful for you both.		
24.	Take care		
25.	[redacted]		
26.	[redacted]		
27.	Senior Lecturer		
28.	Room C.2.30		

29.	Department of Clothing Design and Technology		
30.	Hollings Faculty		
31.	Righton Building		
32.	Cavendish Street		
33.	Manchester		
34.	M15 6BG		
35.	RE: Meeting for results of body scanner analysis		
36.	[redacted]		
37.	Sent: 20 September 2013 08:47		
38.	To: [redacted]		
39.	Attachments:		
40.	Hi [redacted]		
41.	Further to [redacted] email, as suggested Wed the 9th would be best, either between 10:30-12 or between 3-5. Let us know which times are best and we can book in the diary. Looking forward to going over the results.		
42.	Best Regards		
43.	[redacted]		
44.	[redacted] | Senior Lecturer in Fashion Technology | Department of Apparel		
45.	Manchester Metropolitan University		
46.	Hollings Faculty | Righton Building | Cavendish Street | Manchester | M15 6BG		
47.	Re: Meeting for results of body scanner analysis		
48.	[redacted]		
49.	You replied on 20/09/2013 14:11.		
50.	Sent: 20 September 2013 11:58		
51.	To [redacted]		
52.	Attachments:		
53.	*Hi* [redacted]		
54.	*1030 weds sounds good. Are you thinking skyways or at the UNi? Will it be you and* [redacted] *presenting?*	**Communication**	**Communication** – will you be presenting
55.	*If you let me know I will get it on both our diaries straight away, thanks v much,* [redacted]		
56.	Sent from my iPhone		
57.	On 20 Sep 2013, at 07:00, "[redacted] wrote:		
58.	RE: Meeting for results of body scanner analysis		
59.	[redacted]		
60.	Sent: 20 September 2013 14:11		
61.	To: [redacted]		

62.	Cc: [redacted]		
63.	Attachments:		
64.	Hi [redacted]		
65.			
66.	Would it be okay to meet at our new Hollings Faculty at 10:30, Wednesday? [redacted] will be there and has indicated this is a good day and time for him too.		
67.	Take care		
68.	[redacted]		
69.	RE: Meeting for results of body scanner analysis		
70.	[redacted]		
71.	Sent: 24 September 2013 11:11		
72.	To: [redacted]		
73.	Cc: [redacted]		
74.	Attachments: MNU presentation.ppt (303 KB)[Open as Web Page]		
75.	*Hi* [redacted]		
76.	*Yes - 10:30 - 12:00 on Weds 9th @ the new Hollings Faculty would be fine.*		
77.	*What we are expecting within the presentation is the following:*	**Aims and achievements**	**Aims and achievements** – we, expecting, presentation
78.	*1. Spread of height across sample (by Age profile/segmentation)*		
79.	*2. Number of respondents who fell into each age bracket*		
80.	*3. Average size by age*	**Standardisation**	**Standardisation** – average size, age
81.	*4. What was the average/modal body shape (as per MMU classification/algorithm).*	**Standardisation**	**Standardisation** – average, body model/shape
82.	*5. Average measures across the sample and scan who fell into that average size*	**Standardisation**	**Standardisation** – average, measures, average size
83.	*6. Waist / hip / bust averages.*	**Standardisation**	**Standardisation** – averages, waist, hip, bust
84.	*7. Average waist girth for the 45-55 and 55+ age groups with a bust girth of 92/93cm. Relationship between the above 3 measurements (ie difference between each) - see e.g powerpoint attached for suggested presentation of data*	**Standardisation** **Communication**	**Standardisation** – average waist girth **Communication** – powerpoint,

			suggested presentation of data
85.	*9. Back rise / front rise relationship*		
86.	*10. Inside leg average, spread across sample and within age segmentation.*	**Standardisation**	**Standardisation** – average, within age segmentation
87.	*11. Average bust point by age segmentation from Side neck point.*	**Standardisation**	**Standardisation –** average, bust point age segmentation
88.	*Any issues, please flag up ahead of the meeting*		
89.	*Kind regards*		
90.	[redacted]		
91.	*Content of [redacted] attachment:*		



Graph images

All the graphs in this email were developed by a third party. The third party make fit forms and mannequins using body scanning technology and average body dimension measurements from different sections of the population.

Brief for Body scanning event

1. Average measures by age profile (18-35), (35-55) and (55+) for the following points of measure (see attached graphs on slides 2-7);

- Height
- Bust girth
- Waist Girth
- Hip girth – top and lower
- Under bust girth
- Inside leg (along leg) to ankle
- SNP to bust (at fullest point)
- Front rise (to natural waist)
- Back rise (to natural waist)

2. Body shape segmentation for the 18-35, 45-55 and 55+ age groups. JL to discuss the algorithms with MNU to establish which body shapes required.

3. Size 12 average body shape for 45-55 and 55+ age groups (visualised front, back and side shots).
   - Pitch of pelvis
   - Curvature of spine

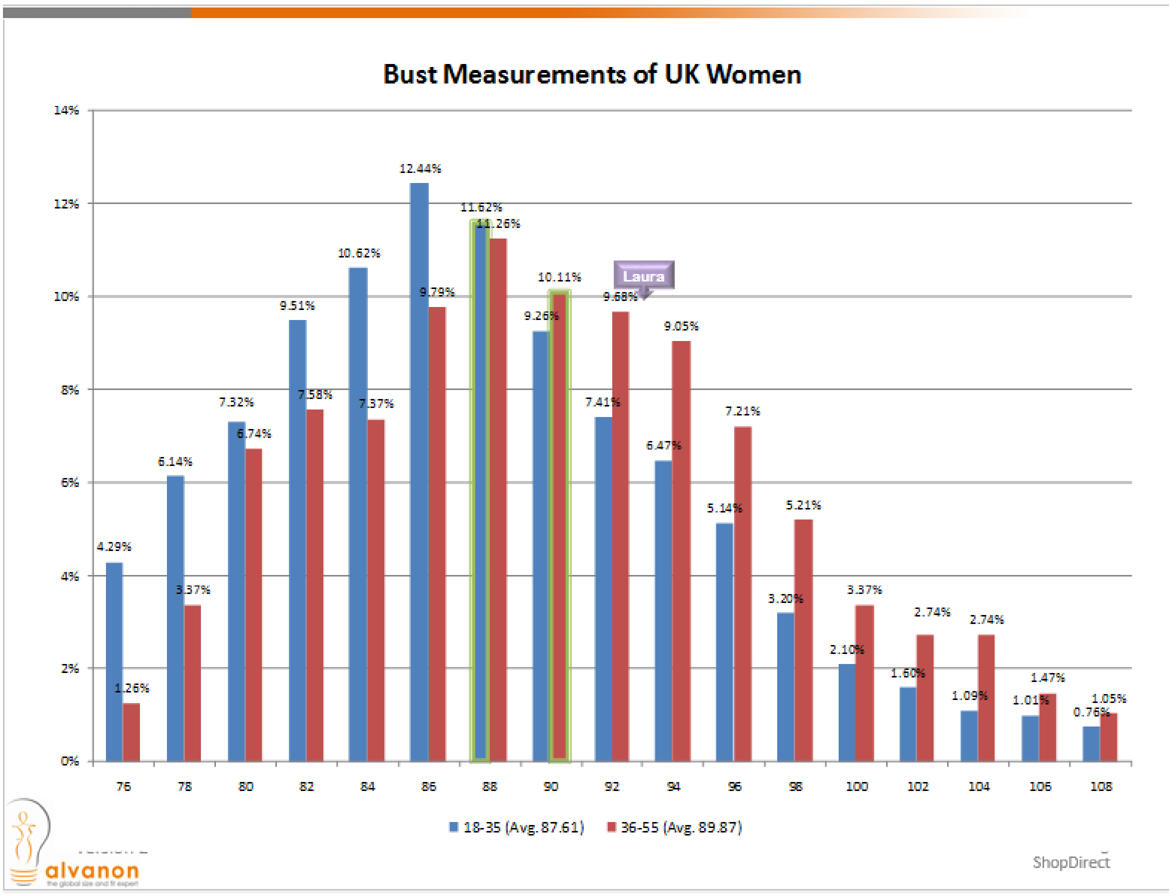
4. Data on number of people scanned in each population, demographic and ethnic group (to context outputs).

5. On-going access to the data for ad-hoc queries.

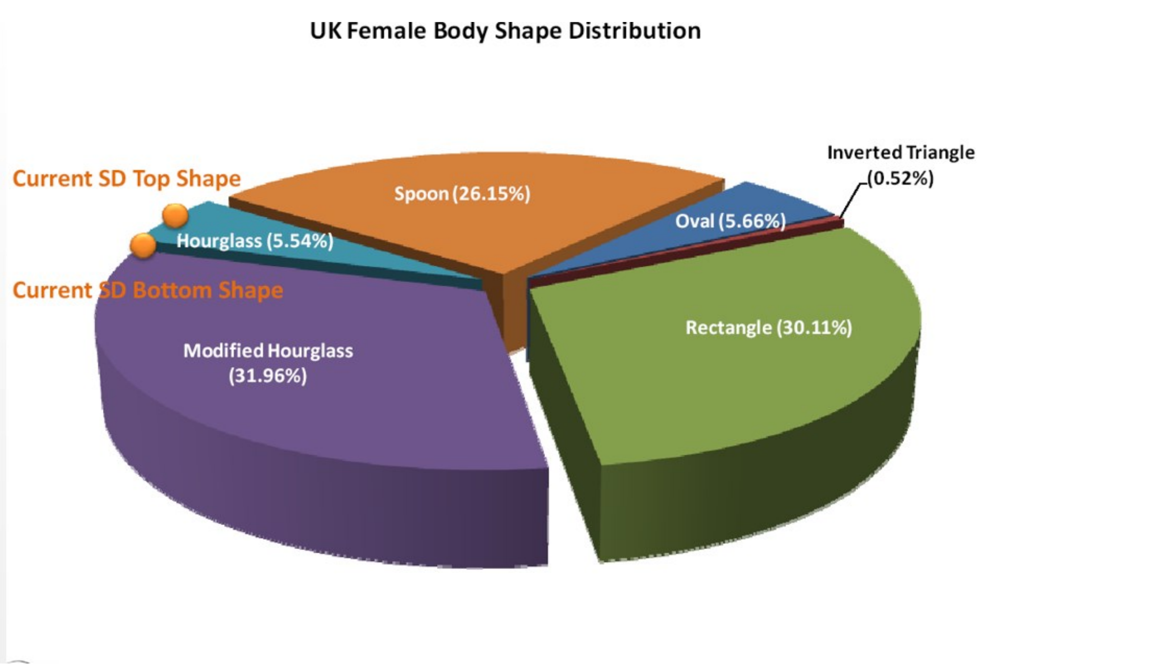
Standardisation - The company is interested in averages measurements concerning the torso region of the body. Though their target demographic is 45+ they are interested in comparing the mature women's body measures to that of a young sample. They are also interested to see how body shape changes or differs through a selection of age categories.

They are particularly interested in body rise front and back and during a meeting the garment tech appeared to think that this region tilts as a women ages. This may be related to the position of the waist, a lowering bust point and a larger abdomen region. This thesis's work has found that some women wear their waistbands at a pitch with the back often being higher than the front.

Time and cost - Finally the company seem to want ad-hoc access to the scan data which means they have at this point no end point to the work.



Bust Measurements of UK Women
Laura
18-35 (Avg. 87.61)
36-55 (Avg. 89.87)
alvanon
ShopDirect



UK Female Body Shape Distribution
Current SD Top Shape
Current SD Bottom Shape
Spoon (26.15%)
Inverted Triangle (0.52%)
Oval (5.66%)
Hourglass (5.54%)
Rectangle (30.11%)
Modified Hourglass (31.96%)

Observations: Girth differentials

- The average woman in the target demographic is:

	18-35	36-55	55+
– Tall			
– Bust			
– Waist			
– High Hip			
– Low Hip			

- Her key shape characteristics are:

	18-35	36-55	55+
– Bust-Waist Differential			
– Waist-Hip Differential			
– Bust-High Hip Differential			
– Bust-Low Hip Differential			

5

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	2
Blue – Time and cost	1
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	2
Forest - Standardisation	8

Italics are the company's words

Non-italics are scan team

Anonymous font are notes

Paragraph 8

Company want the garment tech present as much of the quantitative results could inform their work.

Paragraph 12

Giving advance gratitude indicates that the work will be done to satisfaction/specification?

35.1.21 Correspondence twenty-one

Paragraph #	**Questionnaire results and further analysis of scans**	**Main Themes**	**Associated words**
1.	From: [redacted]		
2.	Date: 25 September 2013 10:36:02 BST		
3.	To: <[redacted]>		
4.	Cc: "[redacted]>		
5.	Subject: Scan results		
6.	*Hi* [redacted]		
7.	*We've now analysed the results from the questionnaires and found that:*		
8.	*97 were exactly the size they thought they were*		
9.	*61 were one size out*		
10.	*23 were more than one size out*		
11.	*And annoyingly 18 we couldn't use because they didn't have the metail size recommendation on.*	**Aims and achievements**	**Aims and achievements** – annoyingly, couldn't use, didn't have metail size
12.	*The batch we want to dig deeper into are the 23 that were more than one*	**Company Research**	**Company Research** – we

	size out (our thinking are that those who are one size out are explainable because they've probably just put on a few pounds or lost a few without being conscious of it (or they're trying to fool themselves that they're still a bit smaller than they are!!).	**Enragement with the customer**	want, dig deeper, 23 more than one size out **Enragement with the customer –** our thinking, those one size out, put pounds on/lost a few, without being conscious of it, they're trying to fool themselves, they are smaller than they are
13.	*To dig deeper into the 23, please could you send us copies or scans of the following 19 (4 did not have the scan number marked on them):*	**Communication**	**Communication** – dig deeper, please, send us copies or scans
14.	[redacted]		
15.	Thanks		
16.	[redacted]		
17.	**RE: Scan results** [redacted] **Sent:** 25 September 2013 13:12 **To:** [redacted]	**Communication** **Time and cost**	**Communication – we, able, send, bust waist hip, longside screen**

	Cc: [redacted] Hi [redacted] We would be able to send you bust, waist and hip measurements for these scans alongside screen shots of them, front and side views with the measurement positions marked on. I may be able to send you the scans as vrmls so you can open them using a web browser, this will have to be early next week as we are currently busy cleaning and preparing the data for the report required on the 9^{th}. Please feel free to call to discuss. Best Regards [redacted]		shots, measurement positions. I send vrml, you open, using web browser **Time and cost** – will have to be early next week, we are busy cleaning and preparing data for required report
18.	**RE: Scan results** [redacted] m] **Sent:** 25 September 2013 13:15 **To:** [redacted] **Cc:** [redacted] *Hi* [redacted] *Bust, waist and hip measurements alongside screen shots of them, front and side views with the measurement positions marked on will be fine.* *We can then use that info to cross check them and if we need to dig any deeper we can do so after that first stage.* *Thanks v much* [redacted]	**Communication** **Research**	**Communication** – measurements alongside screen shots will be fine **Research** – use that info, cross check, need to dig deeper, do after first stage.
19.	**RE: Scan results** [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] **Attachments:** ISME Scans and Measurements.pdf (6 MB)[Open as Web Page]	**Communication**	

	Hi [redacted] Please find attached the screenshots and measurements as requested, I look forward to meeting with you next week . Regards [redacted]		**Communication** – find attached as requested, I look forward to meeting you
20.	To see attachment which accompanied this email open the [redacted] scans and measurements pdf also saved in qualitative [redacted] data file.		
21.	**RE: Scan results** [redacted]] **Sent:** 07 October 2013 10:07 **To:** [redacted] **Cc:** [redacted] *Hi* [redacted] *What we're wanting to do with these scans is re-input them into metail to see if we get the same result again (because these were the ones where the size being recommended was very different to what the customer was buying), but I see on these scans attached we've only got 3 measurements (bust, waist and hip) and not weight or under and over bust measurement (to do the bra size).* *Is there a reason that these measurements are missing?* *Could they be re-sent with all the measurements (including weight) so we can double check them in metail?* *This is probably the most important cell of scans because all of the others resulted in the size that metail recommended being the same as the customer was already buying or being one size out, whereas in this 23 the result was very different so needs to be digged into further.* *Thanks and yes – really looking forward to seeing what your analysis of the scans tells us on Weds,*	**Aims and achievements** **Communication** **Positive about the technology**	**Aims and achievements** – we want, scans, re-input, into Metail, see if same results again, size very different to customer buying **Communication** – I see only got 3 measurements, not weight and bra size, is there a reason, measurements are missing, really looking forward, seeing your analysis of scans **Positive about the technology** – most important cell of scans, Metail recommended, whereas this 23 very different,

	Kind regards [redacted]		needs digged into further

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	2
Blue – Time and cost	1
Purple – Engagement with the customer	1
Red - Company research	2
Grey - Positive about technology	1
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – guidance and confirmation	
Dk grey – scanner accuracy	
Brown - communication	5
Forest - Standardisation	

Italics are the company's words

Non-italics are scan team

Anonymous font are notes

Paragraph 11

If the two technologies could not be effectively 'married' up them the company saw this as a failing.

Paragraph 12

A negative view of the customer by the company if the customer's body size and shape does not conform to their sizing.

Paragraph 13

It had already been explained during meetings and within emails that scan files cannot be sent to the company as they do not possess the software and for ethical reasons. Email ends with just thanks.

The company wish to have the data as they feel they could carry out their own analysis once they have access to the dimensions and visual of each of the 23 scans.

Paragraph 18

This email finishes thanks v much. Perhaps it is because most of the information requested is being supplied over the next few days.

Paragraph 21

He company was appraised of the measurements which were going to be sent and agreed to them in emails above. Communication here has broken down as the company did not state they needed the extra measurements. It is ony after the screen shots and measurement were sent that the company advised the scan team of why and what they were going to do with the measurements.

Paragraph 21 again

The company have already purchased Metail and are keen for it to work accurately so they feel any errors need exploring further.

Interestingly they are less enthusiastic about the fact that is actually recommended the right size for most of the sample.

Was the scanning session a means of testing Metail's accuracy?

35.1.22 Correspondence Twenty-two

Paragraph #	[redacted]'s 23 scans for further analysis	Main themes	Subcategories
1.	[redacted]		
2.	Sent: 11 October 2013 10:03		
3.	To: [redacted]		
4.	Attachments:		
5.	Hi [redacted]		
6.	Hope you are well apologies for disturbing you.		
7.	I have begun to review these scans to put observational comments on shape, posture and LM positioning error when using the Mep developed for the [redacted] scan survey. I will be using the grid and Rasband and Liechty's categorisation of different postures as a guide to determining what posture that person displays and the Excel workbook yourself, [redacted] and [redacted] put together for shape categorisation. What I wanted to know is, are		

	scans on the database in the scanner room now, as I will pick up the scans I don't have next Tuesday when I am in?		
8.	I note that [redacted] has referred to 23 scans when we only have the numbers for 19 and I presume it is just the 19 we shall be providing further comments on.		
9.	Take care		
10.	Paula		
11.	Senior Lecturer in Fashion Technology		
12.	Re: [redacted] 23 scans for further analysis		
13.	[redacted]		
14.	Sent: 11 October 2013 10:58		
15.	To: [redacted]		
16.	Attachments:		
17.	Hi [redacted]		
18.	I will embed the height and weight with the scans in the word document, if you could add your comments to that. I will send it on in the next hour, give me a call on my mobile if you have a chance to talk through the feedback.		
19.	[redacted]		

These emails concerned the report produced for the company and mainly consisted of analysis type as well as communication between members of the team. They mirror and validate the methods used to clean and categorise the scans in this thesis's research.

35.1.23 Correspondence twenty-three

Paragraph #	**Final Report on individual scans** [redacted] **Sent:** 15 October 2013 20:32 **To:** [redacted] **Cc:** [redacted] **Attachments:** Grogan 2013 Dress Fit and ~1.pdf (629 KB)[Open as Web Page]; [redacted] Scans and Measurement~1.pdf (6 MB)[Open as Web Page]	Main themes	Subcategories
1.	Hi [redacted]		
2.	Please find attached the final draft of the report with details of height and weight included as well as [redacted] comments on the scans. I have also included a copy of the paper I spoke about regarding women's experiences of dress selection and fit.	**Communication**	**Communication** – report, details, height, weight, included comments on the scans.
3.	Please could you arrange for me to be sent details of the size categories and height groupings.	**Communication**	**Communication** – arrange, for me, details of size categories, height groupings
4.	I would be happy to discuss further analysis of the data	**Communication**	**Communication** – I, happy,

	we collected and am still awaiting confirmation from CowPR about how they wish to proceed, I understand they will have been in touch with you regarding this.			discuss further analysis, awaiting confirmation , PR understand,
5.	Best Regards			
6.	[redacted]			
7.	[redacted] | Senior Lecturer in Fashion Technology | Department of Apparel			

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – seeking approval	
Dk grey – scanner accuracy	
Brown - communication	3
Forest - Standardisation	

The above email contained an attachment which was an extended version (posture has now been analysed and body shape discussed and calculated) of the first [redacted] scans and measurements pdf. This latest pdf is also saved in the qualitative [redacted] data file.
It also contained the Grogan *et al* (2013) paper on body image. This was given to [redacted] to give some insight into how women feel about clothing fit.

The content of the paper is relevant to the work the company is doing and will help in their analysis. However, the company do not mention if they have read the paper and do not refer to it in meetings or via emails.

35.1.24 Correspondence twenty-four

Paragraph #	Report for [redacted]	Main themes	Subcategories
[redacted]	[redacted]		
2.	Sent: 24 October 2013 13:41		
3.	To: [redacted]		
4.	Cc: [redacted]		
5.	Attachments:		
6.	Hi [redacted]		
[redacted]	[redacted] PR agency, [redacted] PR, have asked that we produce a report from the research we conducted for them with the scanner and combine this with information on body shape and the results of their own survey in customer shape and size.	**Marketing**	**Marketing** – PR agency, report, research, scanner, information, body shape, results of survey, customer size and shape
8.	They have requested the report includes details of:		
9.	Produce a report for the [redacted].com Body Census, looking at the variety of different sizes amongst women from the sample sources stated above.		
10.	**Expectations**		
11.	Produce a 5 page report containing combining	**Aims and achievements**	**Aims and achievements** –

	quantitative and qualitative results of the One Poll, Women's Weekly Live scanning event and existing findings from body scanning an older demographic.		report, quantitative, qualitative, results, One poll, scanning event, findings, body scanning, older demographic
12.	· Includes rich media angles, including: regional split, age split	**Marketing**	**Marketing** – rich, media angles
13.	· Produce a detailed outline of specific new body types and a breakdown of which people across the sample fit into these	**Aims and achievements**	**Aims and achievements –** detailed outline, specific, new, body types, breakdown, fit into
14.	· Develop a new set of body shape classifications to replace the typical apple and pear shapes with a realistic image of the shape of the nation. 4 -6 different shapes would be preferable	**Aims and achievements**	**Aims and achievements** – new body shape classification, replace, typical shapes, realistic image, shape, of nation, preferable
15.	Summarise the research findings, including details which can be used to develop quotes for media use	**Marketing**	**Marketing –** summarise**,** findings, details, used to develop quotes, media use
16.	· Take part in a radio day in November alongside an	**Aims and achievements**	**Aims and achievements** – take

	[redacted] spokesperson to discuss the findings of the research	**Marketing**	part, discuss, findings, research **Marketing** - radio day [company] spokesperson
17.	The above is what we could agree to contractually, they have provided the results of the survey they undertook and we would request they cover travel and expenses for the radio day, though I would not expect they pay for staff time for this. I believe this would take [redacted] and I about 3 days in total to compose and should not cost more than £1.5-2K.		
18.	We should be able to use the standard CFS and need to get it to them asap, let me know if you require further details, I will forward on details of the contact I have at [redacted]PR.		
19.	Regards		
[redacted]	[redacted]		

This email outlines what the company wishes to cover in the report and how they will be disseminate the findings via a PR platform.

Themes	Count of main themes
Pink – Marketing	4
Yellow – Scanner utilisation	
Green – Aims and achievements	4
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – seeking approval	
Dk grey – scanner accuracy	
Brown - communication	
Forest - Standardisation	

35.1.25 Correspondence twenty-five

Paragraph #	Re: [redacted].com report	Main themes	Subcategories
1.	[redacted]]		
2.	Sent: 22 November 2013 14:02		

3.	To: [redacted]		
4.	Cc: [redacted])		
5.	*Hi [redacted],*		
6.	*Many thanks for sharing the link to your bio.*		
7.	*Sorry to chase on the quote, but do you know when we can expect to receive this?*	**Time and cost**	**Time and cost –** sorry chase, when
8.	*Thanks,*		
9.	[redacted]		
10.	On 21 Nov 2013, at 14:44,		
11.	Hi [redacted]		
12.	Sorry, I had received the email but have not had a chance to reply until now. With regard to the shape, the key element is defining the Oval and Diamond shapes as distinct from the rectangle shapes and this requires further development. Whilst I cannot offer a new body shape, the adoption of systems like the FFIT, which are driven by measurable proportional relationships of key body dimensions, allow clothing to be constructed with a greater awareness of how it will be experienced by the consumer.	**Communication** **Aims and achievements**	**Communication –** sorry, had received, not had chance, reply. **Aims and achievements –** cannot offer new body shape, requires further development, clear, age, important factor, shape is defined

	These measurement based categories enabled through body scanning technology move away from subjective classification of shape based on 2D assessment to systems which have much greater relevance to how clothing is developed and how consumers interact with sizing. The next stage for development of shape is determining proportional lengths, the distances between key circumferences and considerations of balance, in terms of the proportions of circumferences to the front and back of the body. It is clear age is an important factor in how shape is defined as we expect certain changes to muscle tone and fat deposition which will be influenced by age.		
13.	In summary the research undertaken shows that many expectations about changing female shape through age occurs and that shape alongside an understanding of proportional relationships is a key requirement when		

	considering the customer in the development of clothing.		
14.	My colleague who collaborated on the report, [redacted] will also be able to provide a quote and I hope this will be with you today or tomorrow. Could you also provide some further information as regards the event on the 27th of November.		
15.	Best regards		
16.	[redacted]		
17.	[redacted] Senior Lecturer in Fashion Technology		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	1
Blue – Time and cost	1
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	

Olive - Privacy	
Teal - Logistics	
Navy – seeking approval	
Dk grey – scanner accuracy	
Brown - communication	1
Forest - Standardisation	1

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

Paragraph 7

Using words and phrases such as 'chase' and 'when can we expect' indicates the PR company is seeking a speedy response from the scan team. Conversely the scan team is not as focussed on speed of response. Judging from the reply below their concern is to accurately outline the findings of the research so far using an academic style of language. Interestingly the scan team had previously been asked if they could provide rich media angles suggesting anything used from the findings could be phrased in more marketable terminology.

Paragraph 12

The academic provides an extended response when asked for a quote by the PR company. This response provides detail which the PR company may or may not find essential to their own work for the company.

35.1.26 Correspondence Twenty-six

Paragraph #	Body shape categorisation	Main themes	Subcategories
1.	[redacted] **Sent:** 25 November 2013 14:44 **To:** [redacted] *Hi [redacted]* *Hope all's well your end.* *We're currently working on the assessment of metail ("check my size") and as part of that analysis, they wanted to look at the people who have used it, cross referenced with the different body shapes as defined in your report.* *However, [redacted] couldn't find the definition of the body shapes that you sent to her. Is there any chance you could resend?* *Also – I remember getting an invite from your or [redacted] to some awards that you're running @ the uni, but I've completely mislayed it! Any chance again you could resend to me?* *Thanks v much* [redacted]	**Research**	**Research –** assessment of Metail, analysis, people who used it, cross reference different body shapes in report
2.	***FW: Body shape categorisation*** [redacted] *This message was sent with High importance.* **Sent:** 02 December 2013 15:58 **To:** [redacted] *Please could one of you send me the below. I need to send to metail, because [redacted] has mislayed the definitions you previously sent.* *Any problem let me know.* *Would be a great help if you could send it by lunchtime tomorrow.* *Thanks in advance* [redacted]	**Time and cost**	**Time and cost –** great, send, by lunchtime tomorrow
3.	Hi [redacted]		

4.	The definitions for the body shapes are detailed in the attached paper.	**Communication**	**Communication** – definitions, detailed in attached paper
5.	Regards		
6.	[redacted]		
	[redacted] send the Lee *et al* paper. This paper is saved to the Qualitative [redacted] data file.		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	1
Purple – Engagement with the customer	
Red - Company research	1
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	

Navy – seeking approval	
Dk grey – scanner accuracy	
Brown - communication	1
Forest - Standardisation	

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

Paragraph 4

The company needs to read the academic paper to ascertain information of the body shapes. This paper has been sent previously to the garment tech but she appears to have mislaid it. This perhaps indicates the company is not inclined to read the paper and would prefer the information to be cascaded to them in simpler terms.

35.1.27 Correspondence twenty-seven

Paragraph #	**Size of the average mannequin**	**Main theme**	**Subcategory**
1.	[redacted]]		
2.	Sent: 26 November 2013 13:41		
3.	[redacted]		
4.	[redacted]		
5.	*I'm sorry we have not shared the press release and briefing notes with you already, there are some concerns around size*	**Communication**	**Communication –** sorry, not shared

	and how we position this, that need to be discussed internally at isme.		
6.	*I shall be in touch with more info as soon as I can.*	**Communication**	Communication
7.	*Thanks,*		
8.	Laura		
9.	Laura Haigh		
10.	Cow PR | Second Floor | 15 Bermondsey Square | London | SE1 3UN		

Themes	Count of main themes
Pink – Marketing	
Yellow – Scanner utilisation	
Green – Aims and achievements	
Blue – Time and cost	
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – seeking approval	

Dk grey – scanner accuracy	
Brown - communication	2
Forest - Standardisation	

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

The PR company is not as quick to share information concerning the press release with the university. They do apologies for the delay and make it clear that it is the company which is holding things up.

35.1.28 Correspondence twenty-eight

Paragraph #	MMU correspondence between staff for the [redacted] event	Main themes	Subcategories
1.	**Re:** [redacted] **event** [redacted] **Sent:** 13 September 2013 06:35 **To:** [redacted]i Hi [redacted] Yesterday was REALLY busy and we did 15 more people over target - the target was 50 / day which was great as it takes longer to scan older women. The technology did not work for the first hour - TC2 wouldn't work and neither would one of the printers. [redacted] got things sorted but we had long queues, I think we underestimated how popular the scanner would be.	**Time and cost** **Scanner utilisation** **Aims and achievements** **Communication**	**Time and cost –** really busy, settle down, always busy **Scanner utilisation –** technology, not work, wouldn't work, got sorted, had long queues, underestimated,

	[redacted] were complaining that the waist measurements were in error and giving the customers the wrong garment size when the information was fed into Metail. I did explain that their definition of 41cm down from the CB neck was a garment and not body measurement and suggested we revert to the [redacted] definition as we have used that quite a lot over the years. They agreed but some of the waist measurements still seemed to be erroneous according to the customers and [redacted]. They also have their own garment tech manually measuring for bra size as they say the scanner measurements are giving the incorrect measurements for bra size. Hopefully today will settle down as I believe the opening day is always busy. I took my car each day and parked in the exhibitor's car park. I think the metro link goes there and there are a number of buses but apologies, I could not tell you their numbers. Take care [redacted] Senior Lecturer		popular, scanner, complaining, waist measurements, error, waist measurements, erroneous according to customers, company, bra measurements incorrect, manually measuring **Aims and achievements** - more people, over target, great, take longer, older women, **Communication** – did explain, their definition, garment, not body, definition
[redacted]	[redacted] PR) response to the [redacted] report		

3.	*Hi [redacted],*		
4.	*This is great.*	**Aims and achievements**	**Aims and achievements –** great
5.	*Only thing, do you have any alternative/ new body shapes we can include? Just an estimate would be brilliant.*	**Aims and achievements**	**Aims and achievements -** only thing, alternative new body shape, estimate, be brilliant
6.	*Also, can you give me a quote to go into our release about the findings?*	**Marketing**	**Marketing –** quote, release
7.	*Many thanks*		
8.	[redacted]		
9.	[redacted]		
10.	*T: 020 7234 9178*		
11.	[redacted]		
12.	[redacted] *PR / Second Floor /* [redacted] *Bermondsey Square / London* [redacted]		
13.	***Winners of over 60 industry awards since 2002 including PRCA Consultancy of the Year***		
14.			
15.	[redacted] (COW PR)		
16.	Reply from [redacted]		
17.	**Re: [redacted].com report** [redacted]]	**Marketing** **Communication**	**Marketing –** radio day, pitching, broadcast

	Sent: 21 November 2013 17:07 **To:** [redacted] **Cc:** s[redacted]pr.com; [redacted] **Attachments:** BODY CENSUS – RADIO DAY DR~1.pdf (82 KB)[Open as Web Page] *Hi [redacted],* *Thanks for your email and for clarifying this. I look forward to receiving the quote.* *In terms of the radio day, we're currently pitching the report in to broadcast stations and putting the final touches to the press release.* *We'll be in a better position on Monday to update you on the schedule and provide you with a full Q&A briefing document which will outline everything.* *In the meantime, I've attached a top line overview of what to expect and where the studio is.* *Let me know if you have any questions.* *Thank you.* [redacted]		stations, final touches, press release, top line overview **Communication – update you, schedule, full briefing**
18.	**RE: [redacted].com report**		

	[redacted] **Sent:** 22 November 2013 17:15 **To:** [redacted] **Cc:** [redacted] **Attachments:** [redacted] quote for [redacted].docx (19 KB)[Open as Web Page] Hi [redacted] I work alongside [redacted] at MMU and was involved in the [redacted] WWL survey and the ensuing report. I have put together my quote for the press release and provided a little information of my clothing industry/academic background, and research interest. There is also a link to my professional profile but I have to say the photo is rather awful. See attached document to view this information. I look forward to firming up the details on Monday. Take care and have a good weekend [redacted] Senior Lecturer in Fashion Technology		

Themes	Count of main themes
Pink – Marketing	2

Yellow – Scanner utilisation	1
Green – Aims and achievements	3
Blue – Time and cost	1
Purple – Engagement with the customer	
Red - Company research	
Grey - Positive about technology	
Cobalt – Fit	
Olive - Privacy	
Teal - Logistics	
Navy – seeking approval	
Dk grey – scanner accuracy	
Brown - communication	2
Forest - Standardisation	

Italics – company's words

No italics – scan team's words

'Anonymous' font – field notes

Paragraph 1

The company also complained again on the second day of scanning to another member of the scan team as they were not happy with the outcomes when marrying the scanner information to Metail. Additionally, they did not agree with the measurements provided for bust circ and under bust circ and had their own bra garment tech manually measuring customers over their existing underwear. For the correct size. The company asked to see the scanner measurement definitions on the first day.

Paragraph 5

The PR company has already read the report which does not mention new body shapes. However the PR company is asking for an estimate new body shapes, which in essence may mean making up new findings.

35.1.29 Correspondence twenty-nine

[redacted]

BODY CENSUS – RADIO DAY

WEDNESDAY 27TH NOVEMBER, FROM 8am APPROX

Activity: Radio day to discuss the results of the isme.com Body Census

Date: 27th November 2013

Times: From 8am

Location: ON Broadcast Communications, 5th Floor, 41-42 Berners Street, London, W1T 3NB

ACTIVITY OVERVIEW

To demonstrate [redacted] commitment to delivering the best shape and fit, the online retailer has launched the [redacted] **Body Census** campaign to capture the current shape of the nation and an accurate picture of the female body today.

Teaming up with Manchester Metropolitan University, [redacted] has developed the Body Census Report. The report is comprised of the following elements:

- The body measurements of over 3,000 women
- Extensive knowledge and research from the Fashion Technologies Research Centre at Manchester Metropolitan University
- Results from the body scanner study at Woman's Weekly Live
- An overview of body shapes and what these mean

NB: The full report including a summary of the key stats will be provided ahead of the radio day along with full briefing notes.

OBJECTIVE

The radio day is an opportunity to showcase [redacted] extensive knowledge, research and authority on body shapes and to empower women to dress their body right.

YOUR ROLE

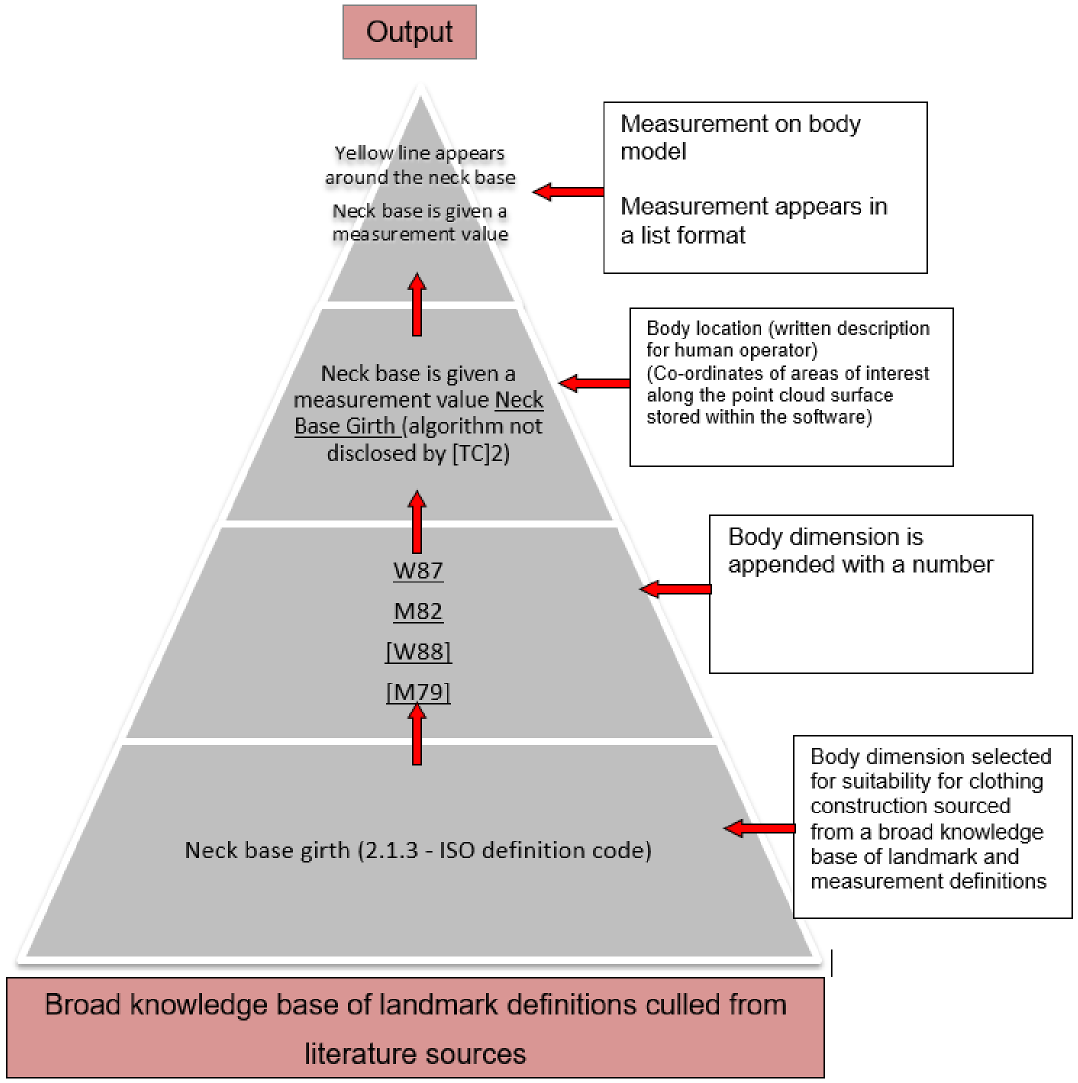
Alongside Carol Vorderman, we'd like you to take part in half a day of radio interviews (approximately 8am – midday).

While Carol Vorderman will act as a spokesperson for [redacted], discussing the top line findings of the Body Census report and what this means for real women, you will be on hand to discuss the technical questions and again, what this means for women.

NB. A succinct list of key messages will be provided in advance of the radio day

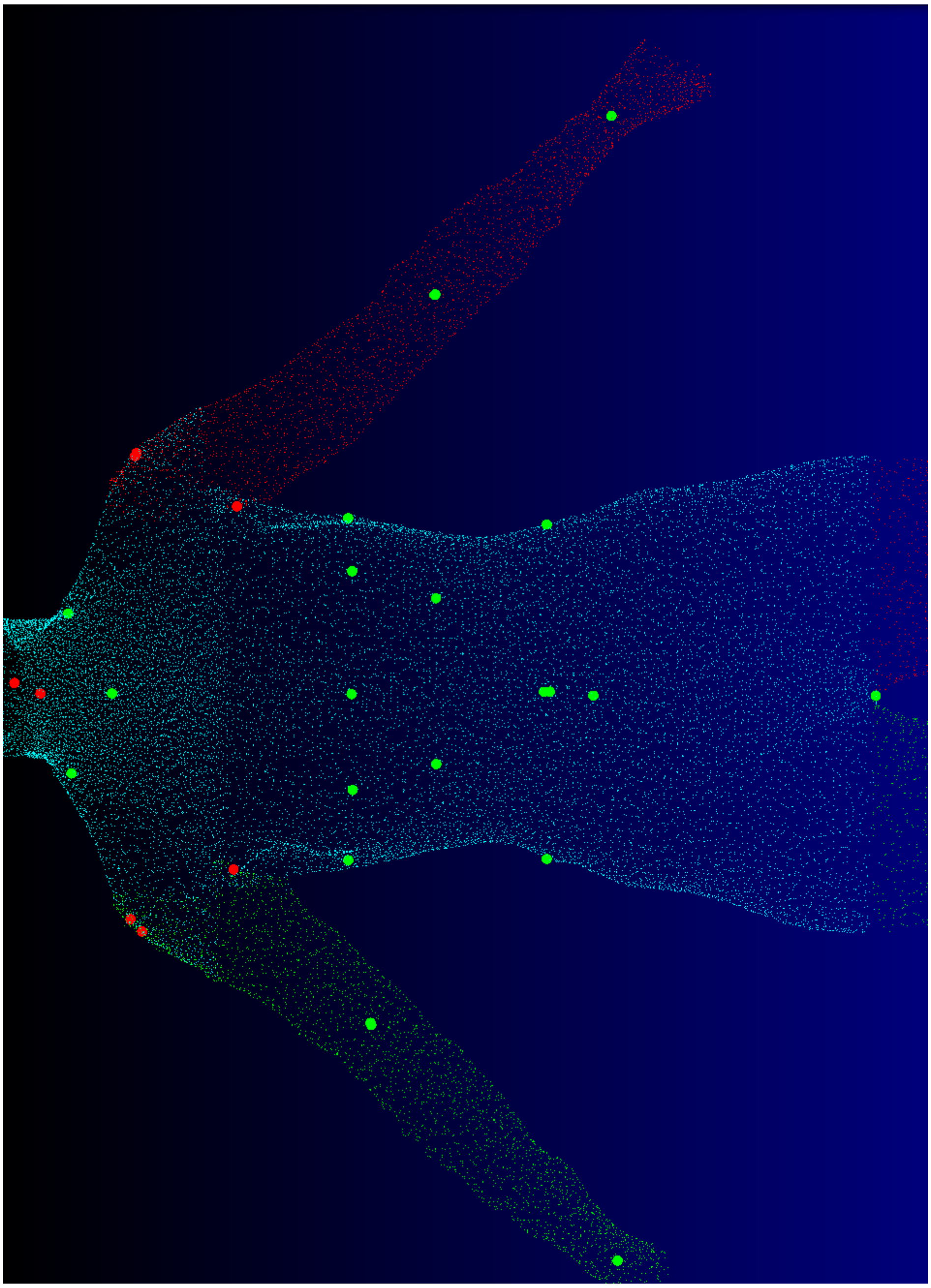
36 Appendix AB

36.1 Model of a measurement extraction file based on active enquiry into the TC² NX16 & KX 16 3D-bodyscanner models.



37 Appendix AC

37.1 Non-contact anatomical landmarking of the human body (arms, chin and torso) by the TC² 3D bodyscanner for anthropometric purposes



38 Appendix AD

38.1 This research's publication of Aim [3]

ESTABLISHING A PRE AND POST-3D BODYSCANNING SURVEY PROCESS FOR ABLE-BODIED UK WOMEN AGED 55 YEARS+ TO DETERMINE AN APPROPRIATE WAIST POSITION FOR GARMENT DEVELOPMENT

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Key words: Gerontology, 3D Body Scanning, Sizing Survey, Product Development, Anthropometrics

Abstract

Change in human body morphology is well-documented for developmental growth from childhood to adult. However, the morphological change from adulthood to older age is less detailed and less discussed within literature concerned with anthropometric application and clothing construction. This, perhaps, explains why females aged 55+ are the demographic most frustrated with the fit of ready-to-wear garments [1]. A prerequisite for the accurate generation of size chart and pattern development relies on precision in the location and demarcation of landmarks [2,3], therefore an understanding of the changes in body size and shape, how this impacts on anthropometric practice, and, more specifically, the body landmarks is fundamental to provide correctly fitting garments patterns for mature women. Consequently, the aim of this research is to establish a pre- and post-3D body scanning survey process for able-bodied UK women aged 55 years and over, giving them the opportunity to self-select a suitable waist location for clothing from four defined waist positions.

A pragmatic, mixed-method methodology was developed to evaluate anthropometric theory and praxis, landmark placement, and subjective body image estimation, to determine the success of their practical application in developing appropriate garment patterns for this demographic.

The methodology consisted of four stages: recruitment of eighty (80) women aged 55+ using the three strategies of convenience, snowball and random sampling; the 3D body scanning of each participant using two TC[2] scanners; the use of a visual aid to allow the self-evaluation of personal waist position for garment development; and the evaluation of the visual and numerical scan data against this self-evaluation.

The findings indicated that recruitment of this demographic is problematic as it is reliant on subject willingness for participation and this group of subjects were often critical of their body morphology. The questionnaire response rate was 67% which reduced the sample size down to 52 women. The visual aid indicated that the participants were able to readily identify the position of their waist regardless of body morphology.

Rectangle, hourglass, triangle and bottom hourglass body shapes were represented in the sample set. The most common body shape shared by this demographic was that of the rectangle and analysis of waist height from the floor position before and after waist landmark modification indicated that the rectangle was the body shape which was most prone to waist placement error from the participant's point of view. All body shapes required waist height modification to the original waist height landmark based on participant evaluation of where they felt it comfortable to wear their waistband. Comparative analysis confirmed distinct variation in subjects' evaluation of waist positioning for a garment and scanner MMU MEP definitions. 59% of participants' waists landmarks were placed differently by the scanner compared to the placement by the subjects themselves.

This study concludes that to improve landmark placement accuracy providing a visual aid to the participant for evaluation in tandem with the practitioner evaluation would be a practice that is useful for common but difficult to locate landmarks, such as the waist. Responses from this visual aid operator evaluation the scan data and more specifically the landmarks.

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Introduction

As humans age, gradual degenerative body changes occur which can affect body size, shape and posture [4,5]. These changes affect garment fit and comfort levels as the body moves away from standard size and shape. Croney [4] lists these changes but focuses on child-to-adult morphological change, whereas information and schematics on adult-to-older age morphological change is less explicated. As body surface measurement data is necessary for the development of garment patterns that accurately fit the body [6,7], a greater understanding of body surface changes is necessary to enable practitioners to accurately extract the right measurements from the right areas of the body for subjects who no longer display a standard body size and shape. This knowledge would enable the development of block patterns that would provide both comfort and a pleasing aesthetic for this demographic.

Gross anatomical knowledge does not appear to be widespread in modern clothing measurement literature, with only Beazley and Bond [2], Kunick [8] and Bunka [9] offering some detail in this area. They all provide a level of detailed guidance on the acquisition of body surface measurements to enable the development of their block patterns but this comes in the form of manual measurements, which present challenges when applied to non-contact measurement technologies. These works provide visuals of the human form and a list of landmark definitions, which refer to gross anatomical reference points on the body from which skin surface measurements are taken [10]. However, Beazley and Bond [2], Kunick [8] and Bunka [9] use visuals and measurement definitions for standard sized female subjects who do not display body deviations away from the standard. Generating block patterns for the older female using this measurement guidance would present challenges.

Morphological change and measurement systems

Adult-to-older age morphological change can affect three phases of anthropometric measurement: how the landmarks are found and positioned; how measurements are taken; and manageability of posture adoption for certain measurements.

Height and postural change

Height is one morphological change linked to the ageing process, which impacts on all of the above three phases. Sorkin *et al* 's [11] study of height change found that height loss is greater in women than men. Lindsey *et al's* [12] study of the effects of hormone replacement therapy on 100 menopausal women correlated height loss with reduced hormone levels due to the onset of the menopause. This study found that subjects who had lower levels of bone density – a result of the menopausal transition - displayed a significant reduction in height [12]. This can also lead to changes in upper body posture resulting in significant angle differences around the shoulder region compared to younger women [13]. Ashdown and Na [13] have explored and quantified upper postural body variation in both young (19-35) and mature (55+) female subjects using 3D-bodyscanning technology. This research found significant measurement angle differences around the upper torso between sample sets, highlighting that because the shoulders rolled forward the cervical portion of the back appeared more hunched. The findings of this study conceded that locating landmarks on the mature sample was difficult as the body changes affected areas where the landmarks are located on a younger person.

Fat deposition

Ley *et al's* [14] study of pre- and post-menopausal women found that post-menopausal participants typically have a higher body mass index (BMI) than pre-menopausal women, and fat distribution tended to be concentrated at the lower torso region around the abdomen. This finding concurs with previous studies wherein mature females had larger waist and abdominal arcs [15, 5, 16, 17, 18]. A study of Korean women's body shapes by Lee *et al* [19] found change also occurred in the bust and hip girths with a thickening of the waist region and an increasingly extended abdomen, something which is common regardless of ethnicity. Furthermore, although it is possible to retain fat deposits around the abdomen region regardless of age, a UK study undertaken by Wells *et al* [20] exploring age-associated body shape changes in young and mature women found that both women in their 20s and over 55 years with the same BMI displayed different body shapes, dependent on their age. Younger obese females retained an indentation in the waist-area whereas mature females displayed higher android fat distribution around the abdomen and waist, thereby having less indentation in the waist region (Figure 2-9). This finding aligns with earlier [17] surveys which established that females over the age of 55 were most likely to display a rectangle torso body shape, which can be defined as where bust and hips circumferences are fairly equal and bust-to-waist and hip-to-waist ratios are low [19].

Non-contact waist definitions

The 3D body scanner works with the topography of the skin generating meshes, consisting of over 100,000 co-ordinate points, to define a human shape [21]. As the scanner is a non-contact measurement technology it 'sees' the surface points and traces pits and elevations in the topography of the skin surface to find specific regions for landmark placement. Therefore, definitions that require manual palpation are redundant for this technology. The TC[2] scanner locates the region of the waist using the spinal curve [22] instead of manual palpation to locate the mid region between the bottom rib and the top of the iliac crest (ISO 8559) which is an international standard manual measurement waist definition. Previous studies have indicated a need for greater landmark definitions for the scanner software to improve the accuracy of measurement placement [23] and this is particularly important for mature women who may experience the lowest rib lying against the top of the iliac crest – known as costo-iliac impingement syndrome - because of an osteoporotic condition [24]. This condition makes the ISO 8559 redundant, as clinically the individual has no longer a gap between the bottom rib and the iliac crest.

Demographical attitudes regarding body scanning

There have been a number of anthropometric surveys with the potential to collect measurement data from women aged 55+ [25,15,16,17]. Many of these surveys report encountering reluctance on the part of the subject to be seen in a state of semi-undress and had to provide specially made garments to protect the modesty of this demographic or did not recruit comparable numbers to the younger demographic sample in these surveys. The introduction of 3D body scanning can counter issues of modesty. The Lee *et al* [19] study investigating women's attitudes towards the scanning process indicated that 64% of older women were open to the thought of having their body scanned for the purpose of pattern development to improve garment fit. However, the study also acknowledged that when questioned whether they would be comfortable showing their scanned body image to friends or family, women who weighed more or who had a high BMI score would be uncomfortable letting others view their scan. This study indicates theoretical openness towards body scanning. However, as this sample group was not actually scanned these results could have been different had participants been required to be scanned.

Self-evaluation of personal waist position and 3D body scanning

Validating self -evaluated waist measurements

Disparate fields of study have explored self-reported body measurement to determine their reliability and validity. Rim *et al's* [27] early anthropometric study of women aged 41-65 years study found that participant's self-evaluated measurement of the waist using manual measurement protocols was very close to the manual measurements recorded by a technician, with no over or underestimation of waist circumference. Guerra *et al's* [28] more recent examination of anatomical location for waist circumference using manual measurement on a sample of 51 adults aged 60-85, remarked that anatomical land marking is problematic in older subjects whose body morphology displayed excess abdominal visceral fat around the torso. Their work indicates that the only way to find the waist on an older female demographic was to palpate the participant's body surface using the skeletal-muscular framework alongside easily identifiable body surface attributes as landmarks. The work confirms that engaging with the participant in this way also provided the opportunity for verbal confirmation from the subject that the practitioner had marked out a landmark that correctly aligned with the subject's perception of where their own waist was.

Song & Ashdown's [29] recent US study assessed the reliability of participant self-evaluated lower-body size and shape using 3D-body scanning technology in conjunction with the SizeUSA survey measurement definitions which places the waist landmark directly on the small of the back. The study compared the scanned body shape against the shape participants believed themselves to be. Importantly, the findings revealed a discrepancy between the self-evaluated waist height dimension and the placement of the waist height by the body scanner with respondents indicating their waist height should be shorter in their view. Furthermore, those reporting most discrepancy between self-evaluation and the scanner were those whose body displayed a fuller silhouette. This does indicate the waist height definition used by the scanner survey differs from where some participants understand their waist position to be, with most variance in subjects who have a fuller figure. Data from national surveys such as SizeUSA has been used for a number of industries including garment product development, so if the waist definition does not correspond to where members of the population who have a fuller silhouette understand their waist to be, garment producers may find issue with the waist on garments developed using this data.

Quantitative and qualitative methods to improve measurement protocols

Haffenden's [30] study provides more targeted insights into the perceptions of older females whose body morphology displays a less defined waist position in her study centered on product development for knitted garments. This study employed mixed method approach using online questionnaires to gather broad opinions of garment fit before moving on to semi-structured interviews and a measurement survey using 3D scanning technology. The work collected key dimensions for garment development and established that the waist was a contentious area because large women do not conform to standard sizing. It also identified that participants were knowledgeable regarding their own body shape and were able to articulate their shape clearly using visual analysis of their body surface contours as well as proportional linear measurements. This work [30] is significant as it acknowledges that new protocols are needed when devising a measurement system for women who do not have a clearly defined waist.

Mature women's requirements and knowledge of garment fit

Recent studies surrounding mature clothing preference [31, 32, 33] indicate this demographic desires clothing which not only looks appealing and is pertinent to their lifestyles but that is developed to correctly fit their body size and shape. Correct garment fit, is the most important aspect when considering a garments purchase [34, 35], with perceptions on fit differing from one individual to another [23]. Research regarding preferences for aesthetic attributes in clothing as a function of both comfort and how individuals view their body image is ongoing. Richards [36] early research found women over 65 years understood their body's physical attributes and had definite ideas on how clothing can be perceived as a corrective medium to balance out or obscure changes in body morphology. It has been established that this demographic is interested in particular garment styling and pattern amendment because of the changes in their body's morphology [19,17,36] or examined anthropometric data to help amend pattern blocks [16].

Interpreting scan data into 2D pattern shapes is already under investigation [37]. However, no current research has solicited ideas on landmark positioning both pre and post-body scanning for the implementation into the pattern, which is central to this study.

Methodology

Recruitment

Sampling strategies

Recruitment of the females participants aged 55+ followed four different approaches: (1) posters were used to advertise the survey placing them in in public areas such as libraries, health clubs and doctors surgeries all situated within the Greater Manchester (UK) environs. (2) a convenience sample of individuals within the Manchester Metropolitan University (MMU) population were emailed. (3) snowball sampling via word-of-mouth contacts. (4) a random sample using the internet and local radio to a three-day scanning event held in Nottingham, UK.

Samples from recruitment approaches (1) to (3) were conveniently accessible to the study and selected using a non-probability sampling technique [38, 39]. In addition to being female and 55+ participants needed to be physically able to stand within the scanning booth for the time it took to capture their body surface data. No restriction was placed on height, body shape or size. The final sample number for scanning was 80. The participant criteria – female, 55+, physically able to stand – was adhered to for recruitment approach (4) but this was deemed a random sample rather than a convenience sample due to the communication medium used to recruit. This type of mixed sampling approach added confidence to the findings [40], as it offered the opportunity to identify if a finding is affected by the chosen method of sampling.

Final sample total

80 participants were recruited and scanned. This sample number reduced as only 52 of the 80 scanned also participated in the use of the visual aid that constituted a part of the methodology of this study. The BS EN ISO 20685:2010 [41] standard recommends a sample size of 40 participants '[as] this will ensure 95 % confidence in the validation test results for large circumferences such as chest, waist, and hip, which are particularly difficult to measure for both traditional and 3-D measurement systems'. As this study used a sample of 52, an increase on the recommended 40, it could be argued that this study justifies a high level of confidence in the validation of its own results.

Data types for mixed methods

Sampling quotas for studies using mixed methods must include a strand that collects 'persuasive' qualitative data collection procedures, and a strand that incorporates rigorous quantitative procedures [42]. This study complies with this approach by gathering qualitative data concerning the thoughts of the participants with regard to the body scanning process and fit preference for a garment waistband, as well as gathering statistical analysis of quantitative dimensional data.

Data collection

Ethics

The scanning process had to be approved by MMU's ethics committee before the survey could take place. Prior to the scan day, subjects were given a written and visual account of the scan process and were informed they could withdraw at any time. This was verbally reiterated when participants arrived. Participants personal details were recorded on a password protected database, which allocated each person with a code for anonymity. Participants were required sign a consent form to be eligible for scanning. All forms were stored in a safe.

During the research field notes were transcribed both pre- and post-scanning so data concerning participants perceptions and reactions to recruitment, and the scanning process including the responses to the visuals were accurately documented.

Measurement Equipment

Two TC^2 scanners – the NX16 and KX16 models – were used to capture body surface data. The KX16 is portable and was used for the Nottingham survey. A customised measurement extraction profile file (MEP) was developed to extract specific height and girth measurements suitable for bodice development. This has been termed the MMU MEP. The waist definition within this MMU MEP has been developed by using the spinal curve to the lumber region and placing the landmark above the small of the back within a

4cm tolerance. The same MMU MEP with the same waist definition was used for the entire sample prior to data analysis.

Participants removed all clothing except their own lingerie – as it was important they wore the intimate garments they would wear normally as this work would later on be developing block patterns to go over the lingerie. Subjects were shown how to stand in the scanner and were scanned three times to ensure a clear scan. Once dressed participants were asked if they wanted to see their scan on screen and if they wanted a printout.

1.1.1 Waist position visual aid

The visual aid (*Fig 1* below) enabled subject participation in the landmark placement evaluation process; something that no other study had done before. The visual aid also facilitated the 'non-contact' nature of the measurement survey, as this was part of the attraction of the process to this demographic. As the aim of this research is to improve pattern development a skirt silhouette was used on the visual aid to articulate fit preference for a garment with a waistband.

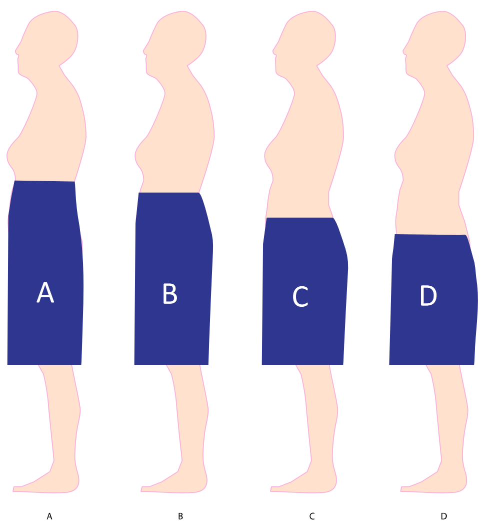


Fig. 1 Where on your body is it comfortable to wear your waistband?

The visual aid was piloted using two MMU academics, both of whom fitted the recruitment criteria and had experience of the clothing product development process.

Feedback from the pilot identified that the visual aid needed to be simple but not idealised. It was also determined that the visuals would depict the following definitions:

Table 1. Landmark definitions used in the visual aid

E. Using the spinal curves and placed above the small of the back with a 2.5” tolerance – [23]
F. Using the spinal curves and placed above the small of the back with a 4cm tolerance – provided within the TC[2] software. This definition was used in the MMU MEP
G. Using the spinal curves and placed at the small of the back – [22]
H. At the point of the top of the iliac crest – [43]

These definitions were selected because they have been used in previous research centered on anthropometric practice and they had enough scope to place the waist at visually different intervals along the torso.

Developing the visual aid

The aesthetic of the image needed careful consideration as the image’s body shape and silhouette (*Fig 1*) needed to represent the demographic of the 55+ woman. Clothing retailers catering for this demographic typically uses images of younger women that are highly idealised and are aspirational in their presentation [44]. This study, however, has used a scan of a 61-year-old woman because the image, although not extreme in terms of corpulence or posture and simplified to protect anonymity, is of a 55+ woman. Her silhouette when compared to a younger women of comparable height and weight was such that her shoulders depict slight curvature, her breasts are positioned lower on the torso than that of the younger woman, and her abdomen protrudes more when viewed in profile. The above landmark definitions could also be applied to her body within the scanner software and this enabled the positioning of the blue skirt seen in the images below. The woman chosen also displayed a rectangle body shape, which, according to earlier studies [17], is a common shape for this demographic.

The images were shown in profile as the MMU MEP used the topology of the spine to place the waist landmarks. Women were asked to examine their own body and determine where they would wear a garment with a shaped waist area or waistband and select one of the four waist positions indicated by the blue skirt.

Data evaluation and reduction

Evaluation of scan data using the chosen visuals

The scans were evaluated on a case-by-case basis. Observations and modifications of the each scan were recorded in Excel. A grid of known dimensions was placed behind the point cloud image and instances of extreme of posture was ascertained using Liechty *et al's* [45] posture guide for reference. Sources of shadows or occlusions were highlighted and their impact was documented. Measurements were then extracted using the MMU MEP as discussed above. Body segments were checked, starting from the chin point and moving downward, to determine correct landmark placement. Questionable landmark positions were compared against the definitions within the software. Automatic waist placement was compared against the visual aid waist position, as chosen by the participant. A different waist definition was manually applied using the software's 'modify point' facility and the centre back waist height landmark. Once the measurement level on the scan aligned with the participant chosen visual measurement extraction was taken again to assess the new measurement position and if any changes had impacted on neighboring landmarks and the ensuing measurements.

Body shape was also calculated for each subject using Lee *et al's* [46] calculations for female body shape categorization (FFIT) programmed into an Excel spreadsheet developed by three academics from the Department of Apparel at MMU. Body shape was recorded in a table alongside body asymmetry and excess fat deposition. The original and amended scans were saved and both were batch processed into an Excel sheet so that original and amended dimensions of waist height from floor could be compared. These dimensions were then subtracted from each other to provide a numerical value to indicate how much the landmark had moved in a vertical plane. For this study, this new dimension was termed the waist height difference (WHD). Body shape was also checked for correlation against the WHD to identify whether any particular body shape was prone to large WHD readings.

Comparative visual analysis

The results of the findings using the visual aids and the body shapes were collated and statistically evaluated. This was to determine if one particular waist position was repeatedly selected and to ascertain any correlation between body shape and waist position amendment within the sample set.

Results and Discussion

Recruitment

South Manchester

Although South Manchester has an approximate population of 36,000 females aged 55+ [47] the poster campaign only resulted to recruit 4 women out of 17 enquiries. Women who made initial contact were curious about the technology and were keen to engage verbally but expressed concerns about their body shape, poor fit, and lack of choice in terms of garment styling. This finding mirrors that of previous studies whereby verbal engagement with participants was relatively easy [26]. However, one of the reasons given for candidates not engaging further with the survey was a reluctance to travel. The NX16 model was used for scanning in Manchester and as this was a fixed structure, it meant that if people wanted to be scanned they needed to come to MMU. Past surveys that have used manual methods have the potential to be more mobile as the equipment is not as large and this may account for greater attendance. Candidates who enquired about the survey also expressed concerns surrounding modesty when they understood that they would have to remove their outer garments. This concern remained even after it was explained that they could watch a video of the scanning process via a web link to help allay fears. Some individuals also were confused that the 3D scanner was a piece of medical equipment.

Only seven members of staff from the university agreed to be scanned despite a university-wide email invitation which covered all academic and administrative staff. The reasons for not participating ranged from a fear of other colleagues seeing their scan data or a lack of interest in body measurement information, both of which were identified in the work of Lee *et al* [26]. Of the seven that were scanned four were known to the team suggesting that the familiarity with the scanning team allayed trust issues.

Purposive and snowball sampling was more successful in recruiting for the Manchester portion of the survey. Women known to the research team were invited to participate with positive results. As these women already knew the researchers there was already a relationship of trust. Participants appeared more content to experience scanning with their friends to support them.

Nottingham

Three clothing retailers were became involved in the recruitment process through contact with a member of the research team. Their involvement meant the event was promoted through radio, as well as using posters and email. The companies also provided participants with incentives to be scanned which could have contributed to willingness to participate.

Observed participants scanning experience

None of the participants from either Manchester or Nottingham complained about the experience of being inside the scanner booth. Fifteen women from the Manchester survey explicitly stated they viewed the scanning experience as an enjoyable event and would be engaging in further leisure activities such as dining out or shopping after they had been scanned. They came as small groups of friends and appeared excited about the experience with some asking if they could return for further scans to check body size and shape as part of an exercising of diet regime. The survey in Nottingham took 3 days and was busier than Manchester. This meant scanning had to quicker to ensure shorter waiting times to avoid people leaving. Greater numbers meant the team spent less time with individuals therefore on day two a mature woman – who had previously been through the scanning experience - joined the team to engage with the participants both pre and post-scanning to help answer any questions and provide each participant with the four visuals.

There was a mixed reaction to viewing the scan image on the screen and it did provoke emotion. The majority of subjects were content to see their image although three women did not wish to view the image on screen and one woman asked for it to be removed from the viewing screen.

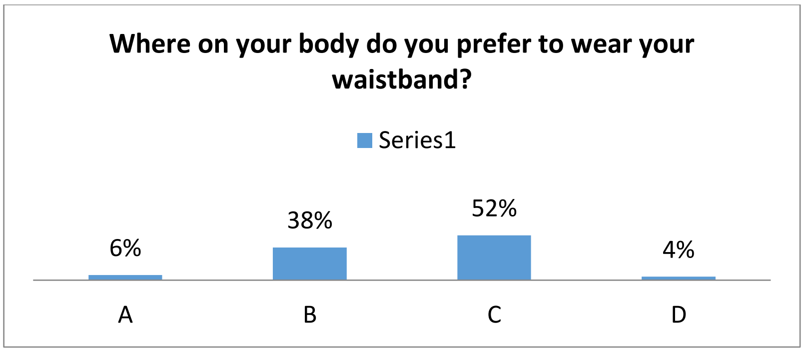
Waist landmark evaluation could have been undertaken between scanner operator and participant whilst looking at the scan image on screen but this could only happen if the participant was comfortable both looking at their image and having a third party scrutinise their image whilst they were present. However, Lee et al's [26] study suggested that some subjects were uncomfortable with this approach, a finding of this study too. When presented with the scan printout subjects frequently expressed displeasure at the image, stating that they appeared larger than they expected or lamenting that they were a more slender shape when they were younger. Participants appeared more focused on the scan image as comments were directed at the image rather than the dimensional data. However, two participants who worked as clothing practitioners complained that the waist measurements were larger than they expected with one participant measuring herself again with a tape measure to prove her point. Comments around the dimensions centred on the fact that often right and left sides of the body were different or a desire to understand which body measurements would be necessary for garment purchasing.

Visual aid results

80 individuals were given the opportunity to use the visual aid but only 52 (65%) women responded by choosing one of the figures from the four provided. 28 participants were sent the visual aid via email to select an appropriate waistband position but only 9 responded. Therefore, the uptake of the use of the visual aid was most successful when offered in person during the scanning process.

It was observed that a number of participants performed a variety of self-evaluation actions prior to choosing a visual. Some women palpated their torso either sitting or standing, some viewed a current waistband placement providing comments on the comfort levels it provided, and some women bent to one side to locate their natural waist or talked to their companions about their thoughts when choosing a suitable visual. No one reported problems with deciding on where they would prefer to wear their waistband and all participants understood and were comfortable with the question.

No participants commented on the fact that the figures in the visual aid were depicted in profile although the participants viewed themselves either front on in a mirror or looking downward onto their body when locating the waist point. No one asked if the positions had particular landmark definitions. Indeed, landmarks were not mentioned by participants at all. Therefore, it could be concluded that subjects viewed the visual aid in an instinctive manner rather than in strictly objective manner.



1.1.1 Fig. 2 Preferred waistband position

Participant preferred waist positioning

52% of the sample identified visual C - around the small of the back – as the preferred position for their waistband. This could be a significant finding for pattern development as the small of the back could be used as a natural anchor point for a garment, depending on body shape, of course. This definition was used for the SizeUSA national anthropometric survey, a definition that according to Song & Ashdown's [29] work was inappropriate for some individuals with a fuller figure.

38% chose visual B indicating they like to wear their waistbands up to 4cm higher than their small of the back. This is the definition used by the MMU MEP and was in line with the UK's most recent national anthropometric survey. Therefore, it could be argued that this cluster of the sample would find UK garment fit appropriate, at least for waist height.

Scan data results

Most common age and body shape

The sample ages ranged from 55-83 with 56% of the sample consisting of women mainly in their 60s. The most common body shape was the rectangle (83%), which concurs with earlier research [17]. Hourglass, bottom hourglass and triangle were represented in the sample so the survey was successful in capturing other body shapes (See *Fig. 3* below).

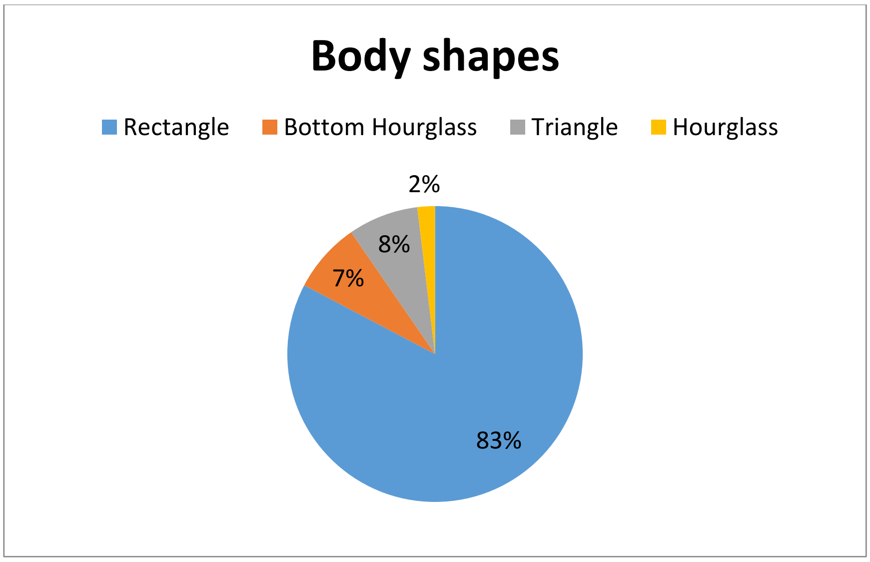


Fig. 3 Body shapes who participated

Landmark modification

60% of the sample required the waist height landmark to be modified to correspond with their chosen visual. Of this 60%, even though a number of subjects had selected visual B – waist = 4cm above the small of the back – and this corresponded to the MMU MEP, the landmark had to be manually adjusted to match the proportions on the visual they had chosen. The reason for waist height landmark modification in this instance was because the scanner software appeared to place the waist directly on or near the under-bust (*Fig. 4*), a result which has occurred in previous research [23].

What differs from previous research [23] is that the waist tolerance within landmark definition was much greater, at around 2.5”, whereas the tolerance used in the MMU MEP was 4cm. The reduced tolerance made this process of moving the landmark to match the proportions of the visual aid more complex but this corresponded to the actual reduction evidenced between the small of the back and the bust in this demographic due to excess adipose fat in the abdomen and bust regions.

The body changes outlined in medical literature have clearly affected the waist positioning for this demographic, which provides a good rational for research of this nature. Nonetheless, regardless of body shape change, these women did not choose to have their waistband aligned to their under bust (see *Fig*. 5) and therefore the back waist landmark had to be moved to satisfy their requirements.

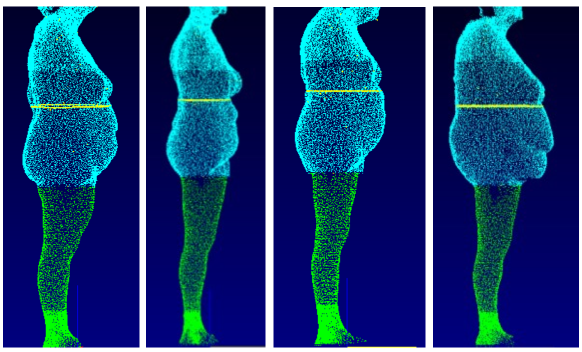


Fig. 4 waist positing lying on the under-bust measurement prior to waist amendment

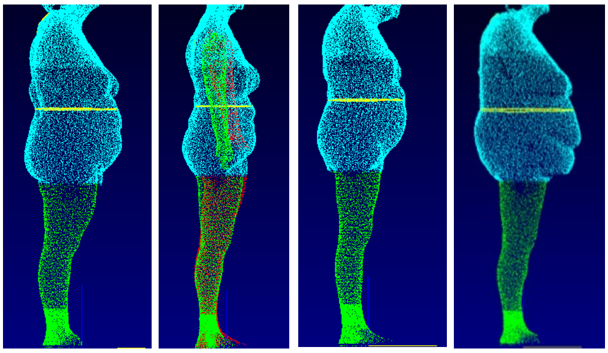


Fig. 5 waist positioning after amendment

Body shape and landmark modification

Fig. 6 below indicates that the rectangle shape had the greatest changes in waist height after modification. Three subjects who were rectangle shapes had chosen visuals which resulted large difference of waist height measurement between – 10.57 cm and 23.67 cm. This occurred because the MMU MEP placed the waist at a significantly different position to the visual they chose. These 3 women either chose visual A where the waist definition is placed high near the under bust and their small of the back was shallow and low on their body or the chose visual D, which is on the top of the iliac crest and the MMU MEP had placed their waist at the under bust. This meant the waist height landmark needed to be moved significantly if it were to match the visual they had chosen.

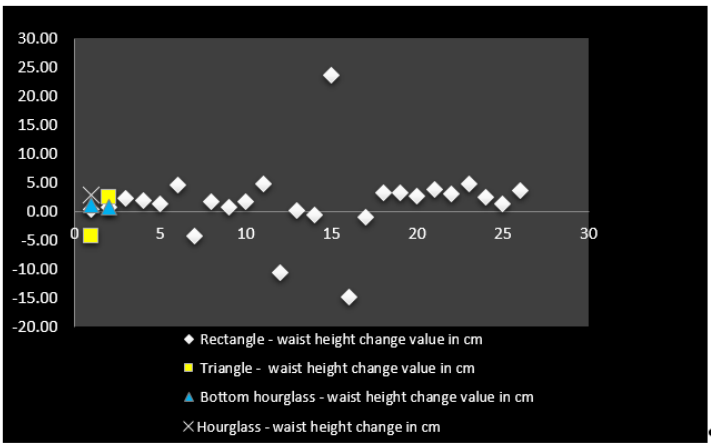


Fig.·6·Waist·height·difference·and·body·shape¶

Fig. 6 Waist height difference and body shape

Conclusion

It is clear that current anthropometric practice using 3D body scanning is insufficient for this demographic as it does not allow for subject engagement as a means of confirming landmark positioning for people with non-standard morphologies.

The new process identified in this study has been specifically developed for application in garment product development. This process has not been discussed in any previous research and is therefore a new finding. This study concludes that to improve landmark placement accuracy a visual aid to the subject for evaluation in tandem with the practitioner evaluation would be a practice that is useful for common but difficult to locate landmarks, such as the waist.

When modifying a landmark position for the female 55+ demographic, the semantics and values of the definition used to direct the software was not successful for some subjects and the operator had to use their observational expertise to match the landmark positioning to the waistband positioning, as requested by the participant.

This study acknowledges the practice entails familiarisation with anthropometric practice and knowledge of using the TC[2] interface therefore a level of training is needed. However, this new process does not require programming skills or detailed medical knowledge of the human body thereby making this a practice which could be readily adopted by clothing professionals.

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39 Appendix AE

39.1 Questionnaire's expanded responses: Perceptions of why particular garments are comfortable

I find this garment comfortable because….	Colour coding		
Trousers as I can get away without wearing tights or heeled shoes with them. Casual tops tend to be longer than blouses and I cannot stand having a gap in the middle.			
My legs are lot slimmer than my torso so trousers hide the shape of my body better and I feel more comfortable.			
I prefer to cover my legs and trousers suit me better.			
Trousers and casual tops - Of ease of movement, and when teaching, I want to make sure that I can lean across a table without revealing underwear.			
if trousers fit well I find them comfortable, warmer in winter, and can be dressed up or down to suit an occasion. …skirts are a flexible alternative to trousers and are comfortable to wear, but I find it hard to find the right sort of style, length, and fit. …casual tops often fit better, are frequently very stylish, can be made from interesting fabrics, and they often reflect fashion trends			
Freedom of movement and suitable for all occasions, smart or casual.			
I can do more in them and also they are not restricitive			
I am an hour glass shape so trousers usually have to have a lot of stretch to fit my smaller waist compared to my hips. Skirts, unless they are pencil skirts, only have to fit my waist. If they are pencil skirts, they have to have stretch in them			
I have always worn trouser as I wear flat shoes			
Loose fitting therefore comfortable			
Now retired so in trousers most days, but as in-between sizes (waist smaller then hips) not always comfortable. Found Per Una jeans fit best.			
Trousers: I walk with a stick and problems standing straight so skirts and dresses look terrible, uneven hem and not decent.			
Trousers and tops: Easy to wear			
I walk a lot, very easy out and about. It's just easy with trousers.			
Cover legs, can bend without showing pants.			
You can mix sizes with trousers and tops.			
Separates are easy to wear.			
Easy to slip into and legs covered when the weather is cool.			
I feel smart in skirts and tops.			
Trousers and tops most times fit better.			
I feel relaxed in trousers and tops/blouses. I don't have to 'adjust' my clothing. I don't have to think about an appropriate length.			
Trousers and tops are easy to wear and cover any bulges.			
I feel comfortable and warm in trousers and tops.			
because of my lifestyle - boating/cycling/walking (ie wear walking shoes with trousers)			

Usually casual tops and jeans as I don't change my clothes during the day and find these allow me to do all the activities I usually do: walking, shopping, gardening.			
Leggings and tops mainly around the house, housework and gardening. Dresses for shopping.			
I have rather a big bust for my height and shirts often gape, casual tops are more comfortable over trousers.			
I find trousers and tops look smart but casual.			
Trousers and casual tops give me more freedom when active. They cover a multitude of sins!			
Trousers and casual tops are easy to relax in and still look dressy			
Dresses and skirts which are loose around the waist or don't have a belt. I dislike anything tight on my waist.			
Trousers and tops are the easiest to get a good fit			
Casual tops: easy to wear			
Trousers and tops fit my casual lifestyle - walking, gardening and very casual socialising.			
I wear a skirt as my legs are too big to wear trousers.			
I mostly wear trousers because I have very problem feet (9AA fitting!) I find it difficult wearing (buying) shoes and rarely able to wear even a small heel.			
Trousers and tops: as I am very active			
Trousers and tops means I can do any activity.			
At the moment I wear trousers because I look after my grandchildren and need 'active wear'. I love dresses but usually cannot find what I need for movement.			
Dresses hold me together well! Can define shape whilst covering stomach.			
Footwear is a problem due to bunions - cannot wear heels unless Sat night! So usually wear jeans due to this.			
I like trousers and casual tops as wearing skirts and tights is not comfortable			
Trousers and casual tops as I have difficulty finding clothes to fit.			

Key

ease of fit

styling

warmth

function

cover up

39.2 Scanning questionnaire: participants reasons for ill-fit in garments

Line number	Transcription	code
1.	My waist is high, I have to wear bigger tops because of my large bust so the tops are big on the shoulders. Jean/trousers that fit around the bottom, crotch and waist are often baggy on the thighs. Size 20 tops gape under the arm.	8, 18
2.	Blouses gape over the bust. The waist is often too loose to get on my hips. Torso length is never long enough especially for swimsuits. My arms are not fat! However the sleeves are tight.	6, 18, 3, 10
3.	Torso length. Hips usually too big due to my large bust size.	18, 13
4.	No reply	
5.	I wear separates and that helps with fit	
6.	I have a large bust and tops gape open. Bodice length is too long as are sleeve length.	6, 18, 15
7.	Can't fit on my waist	9
8.	If the bust size is ok then the hips can be too big particularly shirts and dresses. Trousers can be too tight at the waist and too big on the hips.	18, 1, 16
9.	The sleeves are always too long.	15
10.	Across my shoulders at the front is loose and gapes. Jeans are loose on hips and thighs.	11, 16, 12
11.	Clothes pull across my chest and if buttoned then the button gapes open. A size up in tops is big on my across back, on my bust and across my front shoulders. The waist is either too big or too small!	6, 18
12.	Usually the bust is far too small compared with the rest of the garment.	6
13.	I have broad shoulders so things are tight across my back and the back of my shoulders.	11
14.	T-shirts often gape on the bust. Tops are too short – like a mini on me! T-shirts are tight on the upper arm.	6, 18, 10
15.	I have to wear different sizes on my top and bottom. I have fit problems in all the areas in the picture.	8, 18, 13

16.	I need a larger waist but narrower hip. The crotch is often not long/deep enough on pants.	1, 3, 16,
17.	Things are tight under my arms. The waist is often too loose.	10, 14
18.	My waist is big so this is a problem. Also trousers are rather low – fashion – and prefer them to have a longer crotch.	1, 3
19.	Sometimes the arms are not long enough. The body length of things is too short.	4, 3
20.	I am fairly standard with short legs – so tend to shorten trousers. Shop in river Island, Top Shop fits an S/8 usually. Most fit me but some garments are odd shapes – just don't suit me or just strange pattern?? Bust on occasion can be too big.	18, 23, 24
21.	I have sway back which needs adjustments in the shoulder and back waist.	7
22.	I am long waisted so skirts sit too high. My bust is now out of proportion to the rest of me. My waist is smaller in comparison to my hips.	9, 13, 8
23.	Waist is too high on clothes.	9
24.	I am wider at the hip and when garments fit at the hip, it is too large at the chest. Trouser length sometimes too long.	18, 8, 5
25.	My waist and hips are not in proportion. Dresses may fit on top but then pull on my hips. Some tops and dresses are too big and you can see my bra.	13, 18, 8, 24
26.	The sleeves are often too long. The back length on clothes is too short. The shoulder width is too wide both front and back. The crotch on trousers is too deep and I always have to roll the waistband over.	15, 3, 11, 9, 19
27.	Clothes are tight on my hips and too long in the body length and tight on my bottom.	20, 19,
28.	Too big across my shoulders. Things are too big on my thighs.	11, 12
29.	Hips are too tight. I have a long body length.	20, 3
30.	Clothes are tight on my hips and under my arms.	2, 10

31.	Waist sizing is irregular. There is no correlation between manufacturers. I always have problems with trouser length. Short people are not properly catered for. The hips are often too baggy.	1, 14, 5, 18, 16
32.	Tend to wear jersey so fits ok	
33.	If I buy a bigger size the arms are too long, but length of arms does not vary with increase in weight. Torso length is often a problem with swimsuits being too short, and I don't consider myself to have an exceptionally long torso.	8, 3,
34.	My waist and hips are in-between sizes.	8
35.	Things are tight on my shoulders, too long in the torso and too tight around the neck.	11, 19, 17
36.	The crotch is too loose.	21
37.	The waist is normally too big. I have rounded shoulders so sleeves are too long.	14, 15
38.	No reply	
39.	Sometimes garments are too tight around my abdomen and midriff.	1, 18, 8
40.	Things are tight across my shoulders and too tight on the waist and hip.	18, 1, 11, 20
41.	No reply	
42.	Trousers are frequently not long enough between the crotch and the waist and they feel very tight and uncomfortable. I dislike trousers that do not sit on the waist as I always feel as if I am losing them. Casual tops can often be too short and leave a gap at the waist and if long-sleeved they are often too short.	2, 1, 18,
43.	Shoulders too long, sleeve head comes too far over shoulder. Sleeves too long and tight around top of arm. Crotch length too short, I prefer trousers to fit more onto my waist to help prevent my middle age spread escaping over the low rise waistband. Being petite, length and proportion is always a problem with only a limited choice in a petite range.	11, 15, 10, 2, 18
44.	I don't have problems with fit as I don't wear fitted clothing	
45.	If the neck is too wide it falls off my shoulder. Sleeve length is too long.	22, 15,

46.	Some trousers are too short around the crotch and tight on my waist. Trouser length can be either too long or short. Waist can be too high up on dresses. I have a different size top and bottom so have to by separates.	2, 1, 5, 23, 9, 13
47.	Dresses, if fitted at the hip and bust are too tight at the waist. Blouses, if purchased to fit shoulders and neck, can gape at the bust. Trousers have 'ball room' at the front crotch and often the back rise is too short.	18, 1, 8, 2
48.	In the case of a blouse these are often too narrow across the shoulder. The nape to waist length is often too long and this makes it difficult when wearing due to pouching at the back. Blouse sleeves are nearly always too long. Blouses nearly always are tight across the chest, thus gape open at the front bust area, and I find buttons do not match the size of buttonhole thus they open freely because of the tightness. I always have problems with dress fittings because the nape to waist measurement is too long for me, causing pouching at the back. Dress necks for me are often too large and poorly fitting. Trouser/skirts waists and hips are either too small or too large for my size.	11, 15, 6, 22, 14, 16, 20, 16
49.	If a dress or top fits me on the bust it is usually too large round the waist. Trousers can fit me on the waist too small on the hips and the opposite if they fit my hips they gape on my waist at the back needing to wear a belt. Trouser fit from above knee down but can be loose on the thighs.	20, 14, 16
50.	Necks are too wide as the dress/tops go up in size so does opening, waist is sometimes too high	22, 9
51.	No reply	
52.	I am hour glass so if garments fit on my hips, they are usually too big for my waist. I am a 28G/30FF bra size so dresses and blouses tend not to fit me. If they fit	1, 13, 14, 18

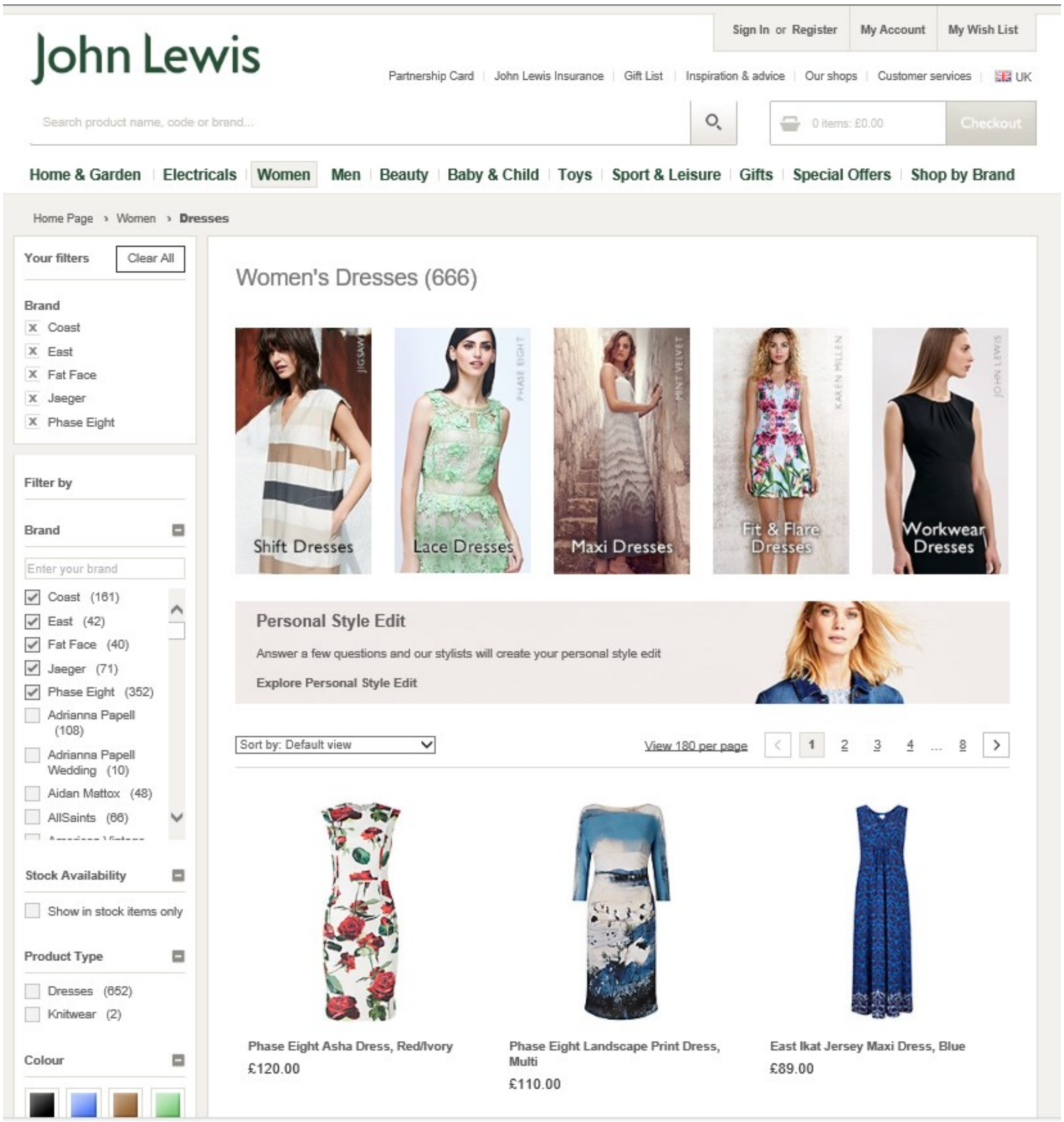
	my upper torso, they are too tight on the bust	

Content coding

Themes				
waist circumference too small 1	front/back rise not deep enough 2	Side neck point to low hip crotch not long enough 3 3	sleeves too short 4	trouser length too long 5
bust too small 6	Highlights issues with posture 7	Does not conform to my body shape 8	Waist placed too high 9	sleeves at bicep too tight 10
shoulder shaping/length incorrect 11	thighs area too loose 12	Different size on top to bottom 13	waist too loose 14	sleeves too long 15
hip area too loose 16	neck circumference too small 17	styling inappropriate for body shape 18	Side neck point to low hip/crotch too long 19	hip area too tight 20
front/back rise too deep 21	Neck too big 22	Trouser length too short 23	Bust too big 24	

40 Appendix AF

40.1 Brands available in John Lewis



41 Appendix AG

41.1 Selected sample for pattern drafting

Selected sample for pattern generation

Subject code	subject shape	(a) W102 Bust girth original	(a) W102 Bust girth cleaned scan	(b) W108 Waist girth original	(b) W108 Waist girth cleaned scan	(c) W87 Neck base girth original	(c) W87 Neck base girth cleaned scan	(d) W12 Back neck depth (back neck rise)original	(d) W12 Back neck depth(back neck rise) cleaned scan	e [40a]-BkNeck-2-WaistLength-(e) original	e [40a]-BkNeck-2-WaistLength- (e) cleaned	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned
\65	triangle	119.26	119.27	107.25	108.84	42.57	42.57	2.00	2.00	38.13	40.33	21.83	21.83
\55	bottom ho	98.59	98.44	75.55	77.88	38.40	38.04	2.00	2.00	35.49	37.06	17.06	17.56
\70	rectangle	116.39	116.63	99.16	100.69	42.00	42.00	2.00	2.00	41.90	43.33	22.82	22.82
35a	rectangle	101.16	101.16	87.70	88.34	37.61	37.61	2.00	2.00	37.86	39.05	18.55	19.55
43_	bottom ho	105.70	105.70	87.72	90.45	43.68	43.68	2.00	2.00	37.28	39.16	15.55	15.55
36_	rectangle	88.19	88.19	71.84	71.84	36.54	36.54	2.00	2.00	40.30	40.30	12.97	12.97
23_	hourglass	108.22	109.24	86.20	86.20	39.94	39.94	2.00	2.00	40.64	40.64	17.36	17.36
25a	bottom ho	96.02	96.57	78.65	80.80	36.37	36.38	2.00	2.00	34.45	36.05	14.97	17.48
23_	bottom ho	95.11	95.11	80.77	80.77	37.51	37.51	2.00	2.00	37.76	37.76	16.93	16.93

j

h [??]-SideNeck2 Waist-overbust-(h) original	h [??]-SideNeck2 Waist-overbust-(h)cleaned	g [??]-SideNeck2Bust-R-(g) original	g [??]-SideNeck2Bust-R-(g) cleaned	I W83 Xback before cleaned	I W83 Xback after cleaning	j W85 X frnt before cleaning	j W85 X frnt after cleaning	k W91 R shoulder length before cleaning	k W91 R shoulder length after cleaning	LW86 bust to bust before cleaning	L W86 bust to bust after cleaning	m W94R width of armhole before cleaning	m W94R width of armhole after cleaning
43.50	44.97	34.21	34.20	37.79	37.79	41.37	41.37	14.84	14.84	26.46	26.46	14.77	14.77
41.23	42.34	29.08	29.29	33.04	32.14	29.24	27.05	10.90	11.60	19.57	19.57	13.32	13.32
46.06	47.37	33.52	33.52	39.40	39.40	39.70	45.06	15.00	15.57	23.61	23.61	13.8 (L)	13.50
41.04	42.15	27.69	27.69	27.18	32.65	37.48	37.49	11.92	11.92	23.45	23.45	15.41	14.82
44.11	45.68	32.04	32.04	29.59	29.59	42.64	42.64	12.42	16.20	23.99	23.99	17.68	17.68
41.27	41.27	25.53	25.53	32.34	32.34	30.26	30.26	10.57	13.50	17.08	17.08	10.48	10.48
44.07	44.07	26.96	26.96	33.00	33.00	33.30	40.43	9.25	13.10	23.49	23.49	18.86	15.32
41.54	42.42	30.06	30.06	27.21	32.77	32.02	37.81	7.84	14.90	21.28	21.28	17.53	13.30
39.09	39.09	27.36	27.36	32.11	32.10	37.20	37.20	13.44	13.44	23.12	23.12	12.33	12.33

each grouping shares a similar height

samples were selected according to height, amount of modifications and to give an even spread of body shape classifications

0360FA65	0621fa25a	0650fa36_	height group from 153-153.5
0361FA55	0271fa23_	0618fa35a	height grouping from 165.1-166.5
0648FA70	0669fa23_	0703fg43_	height grouping all 165

no young participants in the shorter height groups and no over 55s in the tallest height groups

41.2 Examples of batch processed measurements from both modified and unmodified scans for the armscye region of a bodice

18-25 age cluster

f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	Value difference	k W91 R shoulder length before cleaning	k W91 R shoulder length after cleaning	Value difference
18.6	18.6	0.0	13.0	13.0	0.0
12.8	16.0	-3.3	10.9	12.7	-1.8
15.1	16.7	-1.6	7.8	10.8	-3.0
15.0	16.4	-1.5	8.1	10.7	-2.6
12.9	13.7	-0.8	5.9	8.7	-2.7
14.4	14.4	0.0	10.9	9.0	1.9
15.8	15.8	0.0	6.9	9.6	-2.6
17.1	17.1	0.0	13.3	10.7	2.7
14.3	14.6	-0.3	12.3	12.3	0.0
16.1	16.1	0.0	12.5	12.5	0.0
15.6	16.5	-0.8	7.9	11.5	-3.7
16.6	17.8	-1.1	6.1	12.6	-6.5
17.4	17.4	0.0	13.9	13.9	0.0
14.8	14.8	0.0	8.0	8.0	0.0
15.6	15.6	0.0	11.9	11.9	0.0
18.1	18.1	0.0	12.9	12.9	0.0
15.3	15.3	0.0	11.6	11.6	0.0
18.7	18.7	0.0	12.7	12.7	0.0
14.1	14.1	0.0	12.7	12.7	0.0
14.8	14.8	0.0	11.5	11.5	0.0
15.9	15.9	0.0	12.2	12.2	0.0
15.2	15.2	0.0	7.8	11.9	-4.2
16.1	16.1	0.0	11.9	11.9	0.0
17.4	17.4	0.0	9.3	13.1	-3.8
15.8	15.8	0.0	7.9	11.6	-3.7
17.4	17.4	0.0	14.6	14.6	0.0
18.1	18.7	-0.6	11.1	11.1	0.0
15.3	15.3	0.0	10.8	10.8	0.0
19.7	19.7	0.0	13.9	13.8	0.0
16.2	16.2	0.0	13.2	13.2	0.0
16.8	16.8	0.0	12.5	12.5	0.0

35-45 age cluster

f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	Value difference	k W91 R shoulder length before cleaning	k W91 R shoulder length after cleaning	Value difference
18.7	19.3	-0.6	13.6	17.4	-3.8
18.9	18.9	0.0	13.1	13.1	0.0
17.5	17.5	0.0	12.1	12.1	0.0
18.6	18.6	0.0	16.2	16.2	0.0
19.5	19.5	0.0	16.0	16.0	0.0
18.1	18.1	0.0	14.0	13.9	0.0
18.6	18.6	0.0	12.6	12.6	0.0
17.2	17.2	0.0	14.3	14.3	0.0
13.4	14.7	-1.3	12.9	12.9	0.0
12.8	14.9	-2.1	12.3	12.3	0.0
19.2	19.2	0.0	7.7	11.3	-3.6
17.1	17.1	0.0	13.4	13.4	0.0
17.6	17.6	0.0	12.7	12.7	0.0
18.6	19.5	-1.0	11.9	11.9	0.0
18.8	18.0	0.9	14.7	14.7	0.0
14.9	15.2	-0.2	7.2	10.0	-2.8
13.0	13.0	0.0	10.6	10.6	0.0
16.2	16.2	0.0	14.8	13.3	1.5
15.5	15.5	0.0	12.4	16.2	-3.8
17.7	17.8	0.0	9.5	11.4	-1.9
17.0	17.0	0.0	9.4	13.1	-3.7
12.5	12.7	-0.2	7.4	10.5	-3.1
16.8	16.8	0.0	12.8	12.8	0.0
18.0	18.0	0.0	13.1	13.1	0.0
19.2	19.2	0.0	11.8	11.8	0.0
18.5	18.5	0.0	11.6	11.6	0.0
21.1	21.1	0.0	14.3	14.3	0.0
19.1	19.1	0.0	10.2	12.2	-2.1
17.3	17.3	0.0	10.8	10.8	0.0
18.6	18.6	0.0	13.3	13.3	0.0
15.9	15.9	0.0	8.6	9.8	-1.2

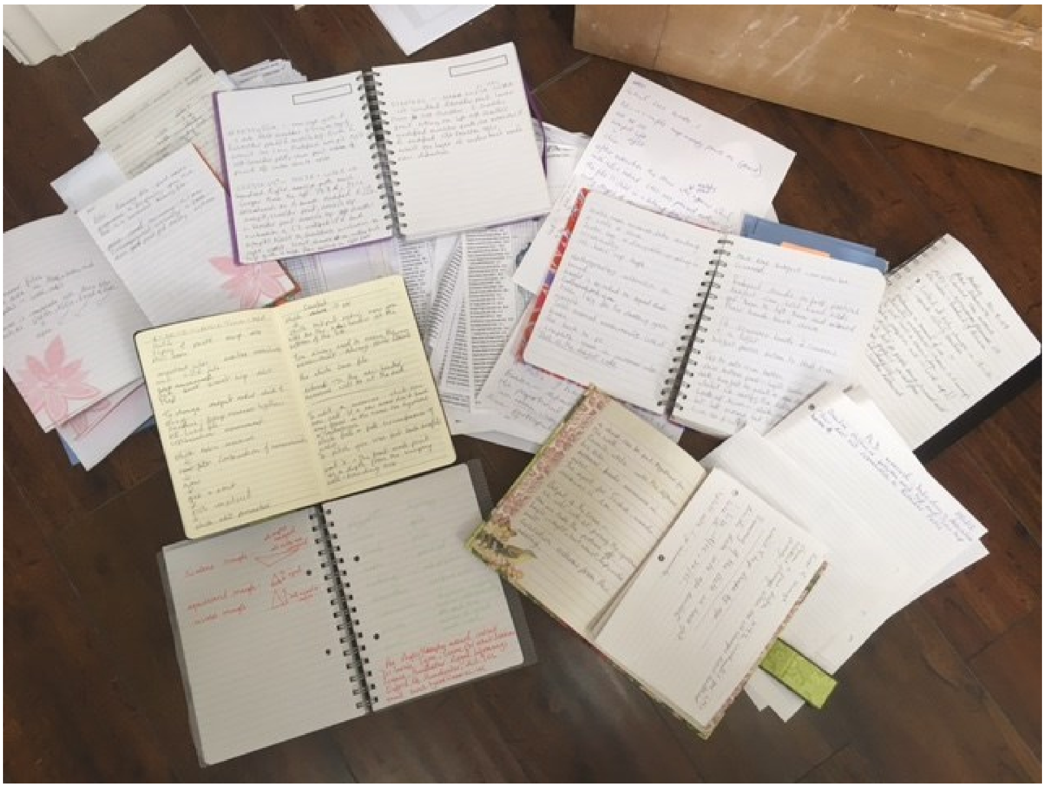
55+ age cluster

f armhole depth (f) [15.1]-ScyeDepth_BkCoutour original	f armhole depth (f) [15.1]-ScyeDepth_BkCoutour cleaned	Value difference	k W91 R shoulder length before cleaning	k W91 R shoulder length after cleaning	Value difference
20.08	20.08	0.00	10.92	10.92	0.00
*** Error *	22.01	#VALUE!	49.86	7.87	41.99
18.42	18.93	-0.51	5.28	10.35	-5.07
19.42	19.42	0.00	11.96	11.96	0.00
16.71	16.73	-0.02	8.36	11.14	-2.78
19.03	20.84	-1.81	14.17	15.47	-1.31
17.02	18.28	-1.26	14.85	10.14	4.71
21.83	21.83	0.00	14.84	14.84	0.00
17.06	17.56	-0.50	15.00	11.60	3.40
20.94	20.94	0.00	10.20	12.13	-1.93
19.63	19.88	-0.25	11.71	11.71	0.00
17.40	17.40	0.00	11.66	11.66	0.00
19.51	19.51	0.00	13.60	13.60	0.00
15.29	15.29	0.00	13.34	13.34	0.00
20.15	20.15	0.00	4.32	3.54	0.78
16.97	17.66	-0.69	9.06	9.23	-0.16
22.82	22.82	0.00	10.50	15.57	-5.07
17.45	17.45	0.00	12.33	12.33	0.00
17.57	17.57	0.00	14.52	14.53	0.00
20.25	20.25	0.00	12.43	12.43	0.00
12.73	14.18	-1.45	8.87	11.11	-2.23
19.40	19.40	0.00	9.87	11.23	-1.35
19.67	19.67	0.00	8.60	8.60	0.00
19.40	19.63	-0.24	9.21	9.70	-0.49
17.25	17.25	0.00	8.72	12.08	-3.35
17.46	17.46	0.00	12.72	12.72	0.00
12.95	15.20	-2.25	6.97	8.78	-1.81
29.28	25.34	3.94	14.51	14.39	0.12
18.01	18.72	-0.71	8.48	12.39	-3.92

42 Appendix AH

42.1 Images of some of the field notes written during the period of experiential learning of the TC^2 3D bodyscanner

*Please note not all notes are shown as they included confidential information such as passwords, user names, participant codes, technician's details etc.



TO OPEN THE COMPUTER.

LOG ON WITH STAFF # + PASSWORD
THEN ANOTHER POP UP APPEARS.
TYPE IN administrator leave password
blank.

TO OPEN THE DATABASE.

GO TO SHORTCUT TO SCANNER DATA
BASE V4 (DOUBLE CLICK)
POP APPEARS
[redacted]

order key – SM126. – Room 9.
SM128?

To see Landmarks – modify point
click control to move them.

MH.
~~0573~~ 0573FA63 – L634
0574FA71 – M714
KL.
~~0584FA86~~.
chin neck armpit – red.
Why are the landmarks colour coded?

Explaining the Scan process + 2 people.
Showing the Scanner. – 5:31 mins.

Filling in the form. – 56 – 1:14 mins
80 – ~~1:25~~ 2:18.

measuring – 56 – 80 –
Scanning itself – 56 – 80 – 9:16.
8:07.

getting change – 2:20 – 56
/ scanning into 3. 2:46 – 80

0584FA56 – N564
0585FA79. – 0794.

BODY SCANNER TRAINING DAY.

2 people always present when a person
is being scanned.
Scans are anonymous
2001 Size UK
context & consent on pc near the
door.
Scanner database on desktop.
↓ double click.
need a password to get into the database
(a[redacted]mer.
① informed ethical consent (poster
above scanner.
② consent form is on database.

③ 5 manual measurements classification
measurements e.g height weight etc

participant fills consent form on line.

need name, post code, phone number or email (important to verify we have actually used a real person).

ethnicity, age, gender
other & hyphon – subject code
need this
before a person writes their ethnicity

click pink panel to print a copy
return to subject detail sheet.
click to create a new record.
The ~~Shoe~~ info sheet is auto saved.
manual measurements can be detailed on the info sheet.
info sheet must ~~be~~ but signed by participant, and 2 technicians

Signed sheet is left with the technician.
Blank copies can be printed off.
TO SCAN.
Click open access scan.
See TC2 icon → click
↓
turn power switch on on scanner.
Top right inside scanner – see picture near monitor.

keys to wardrobes in draw (lefthand) in desk near door. Keys to these draws are with [redacted]
underwear on top of underwear.
lycra shorts maybe made.

~~cab~~, cupboard near changing r

to zoom hold left + right down.

There is a check list on the wall.

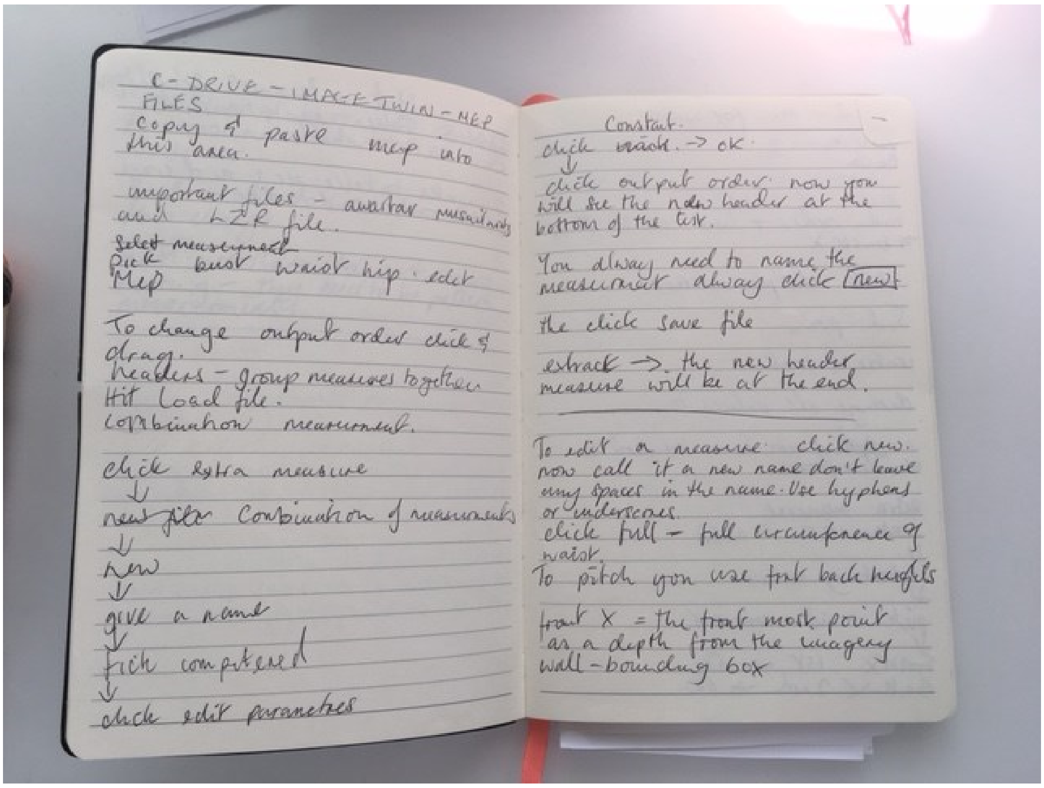
Go back to display all measurements.
Zoom in to see the landmarks (yellow dots).
View modify point allows you to replace the landmark point then save a new file.

You can set the Map.

view body model, parts or slice
it does foreshorten the body.

Booking system will be online. rm booked for 2 days a week.

Calibration looks at accuracy of overlaying images – a test.



C-DRIVE – IMAGE-TWIN – MEP FILES
copy & paste mep into this area.

important files – avatar measurements and LZR file.
Select measurement
Pick bust waist hip. edit
Mep

To change output order click & drag.
headers – group measures together
Hit Load file.
combination measurement.

click extra measure
↓
new file Combination of measurements
↓
new
↓
give a name
↓
tick completed
↓
click edit parameter

Constant.
click waist. → ok.
↓
click output order. now you will see the new header at the bottom of the list.

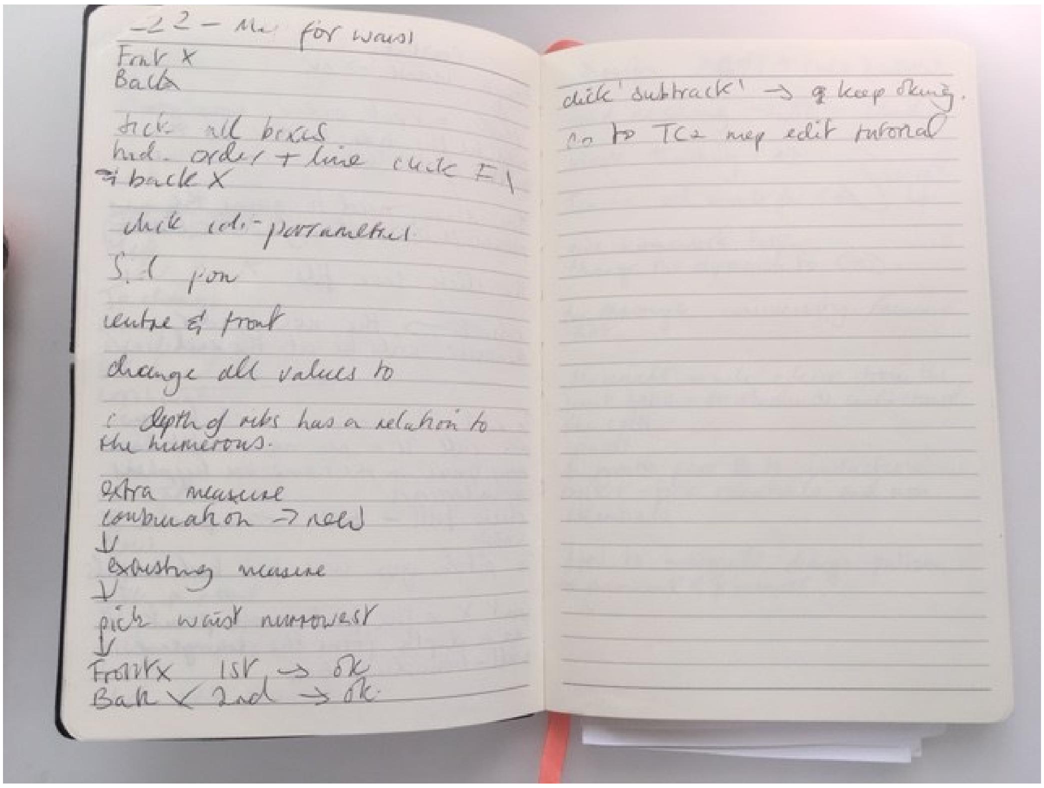
You always need to name the measurement always click $\boxed{\text{new}}$

the click save file

extract → the new header measure will be at the end.

To edit a measure click new. now call it a new name don't leave any spaces in the name. Use hyphens or underscores.
click full – full circumference of waist.
To pitch you use front back heights

front X = the front most point as a depth from the imagery wall – bounding box



–22 – Me for waist
Front X
Back

tick all boxes
hid. order + line click F1
& back X

click edit-parameter

S. L pon

centre & front

change all values to

c depth of ribs has a relation to the humerous.

extra measure
combination → new
↓
existing measure
↓
pick waist narrowest
↓
Front X 1st → ok
Back X 2nd → ok.

click 'subtract' → & keep doing.

go to TC2 mep edit tutorial

43 Appendix AI

43.1 Gill et al (2014b) Lugano paper of which this researches findings contributed

5th International Conference on 3D Body Scanning Technologies, Lugano, Switzerland, 21-22 October 2014

Practical Considerations of Applying Body Scanning as a Teaching and Research Tool

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http://dx.doi.org/10.15221/14.259

Abstract

Used in specific ways, body scanning technology can provide greater understanding of the body and its relationship to clothing. However, body scanning is still a developing technology and little is known about the practical applications and limitations of its operation within the education environment. Further to this, whilst there have been many high profile body scanning surveys, there still appears to be little accessible information on the practical issues of body scanning or data derived from scanning. With reference to live industry and academic projects, and the application of this technology within a UK university, recommendations are provided in the following areas: supporting structures and methods to enable; long term research, short term; accruing of data that can be seen as comparable to that collected in other locations and by other teams. Importantly processes and data captured during scanner use have little standardisation and each operator is expected to develop their own structures for training, data collection, assessment, storage and application. This can be extremely difficult without accessible examples of structures and processes previously applied. The team operating this scanner have found a diverse number of uses and developed protocols for ethics and storage that ensure data collected can have long term relevance as a resource in the increasing global arena of big data and collaboration anticipated by existing funding sources. Fundamentally, recommendations are made regarding body scanner supplier interventions that would enable the easier application of this technology and ensure data is comparable and has the greatest value for each and all operators. It is hoped through the adoption and provision of resources to support consistent scanning and data storage the current data collected on a small scale by varied users can have the greatest opportunity for future use collaboratively across different user groups.

Keywords: 3D body scanning, product development, fashion education, ethics, anthropometric exploration.

1. Introduction

Body scanning, as a relatively new measurement technology, offers great opportunities when assessing the body for clothing product development. Historically scanning has been celebrated as a revolutionary method of collecting data of large populations used to inform sizing systems for mass produced clothing. However although many large scale surveys [1, 2] have been conducted, they have arguably not benefitted industry or improved sizing practice as much as was predicted. This paper is written from the perspective of the clothing practitioner and assesses the application of scanning technology within clothing practice. It identifies a number of areas developed to support the practice of using scanning as well as problematic areas that have hindered progress and the ability to develop effective working methods that could be used to benefit industry.

There are unique challenges to body scanner users who are trained in traditional manual methods of measurement for clothing product development and the ability to contextualise data derived from the scanner is not always easy. Further difficulties arise as unlike traditional manual measurement methods there is limited detailed information describing the undertaking of surveys, the definitions of measurement and the analysis of data. Much of the undertaking and analysis of early measurement surveys provides clear instructive guidance on all aspects of collecting and analysing the data [3, 4] and this has often influenced more up to date surveys and guidance on product development literature [5-7]. The information available in the public domain for major body scanning surveys is scant and very few experienced users and companies have detailed data on measurement definitions, which are central to applying the resulting scan data accurately in product development [8]. This scenario provides a set of unique problems for users of body scanning and this paper will focus on some of these issues as well as the required infrastructure to run body scanners in an educational environment. Whilst the teams experience of body scanning is related to the practice of operating TC2 scanners for academic and industry projects, this experience has evolved in the wider context of increasing use and possibilities of body scanning. Therefore, whilst reflective experiences detailed in this paper relate directly to the TC2 scanner, the issues are more universal in nature and reflect some key considerations of body scanning for product development.

2. Understanding body scanning

Body scanning as the means of capturing 3D objects and rendering them in electronic environments through image capture devices is recognised to provide greater depths of data than manual methods of defining the body for clothing [9]. Not only does it support advanced methods of analysing the body [10-12], there is also the opportunity to explore new methods of product development like pattern development from the scanned body [13, 14]. There are even standards, to guide on its application as a measurement tool [15], though these are merely reference measurements [16], which do not adequately recognise the possibilities of this new technology [17]. An important consideration is that these standards have evolved from manual anthropometric methods which require visual and tactile analysis of the skin to successfully locate landmarks from the skeletal structure. 3D-bodyscanning relies on surface geometry, where the body surface is formed as a mesh comprising of a collection of co-ordinate points and triangles [18] This non-contact method of measurement eliminates the possibility to use traditional palpation to identify landmarks on the body, therefore the level of precision when detecting and locating landmarks is dependent on a clearly written description which inform the programmed algorithm. Explicit information of the descriptions informing the algorithms and the algorithms themselves are commercially sensitive proprietary information and, as such, part of a company's competitive advantage, which results in a reluctance to divulge information ([19]. Consequently, without this information, it is difficult to ascertain whether the software has accurately located the landmarks without further investigation at the individual scan analysis stage. Whilst the body scanner has had extensive use in national measurement surveys [1] and has been validated as offering comparable measurements to manual methods [20], little is known about the practical applications of this technology. In contrast much of the methods and even some of the data of historic surveys are published and accessible to guide on future developments [3, 4, 21, 22]. Details from existing 3D scanning surveys can be found within disparate literature sources, though none provides the level of detail found within historic literature on measurement surveys.

Several international anthropometric surveys have been undertaken to collect population data of body size and shape. Retailers, academics and government departments have together developedsurveys, such as SizeUK [23], SizeUSA [24] and Size Korea [25]. The details of each survey can be found in two ways. The first being the marketing literature which accompanies the scanner brand. A visit to TC[2] (website?) promotes its involvement in the SizeUSA survey and Human Solutions (Vitus) also publicises its involvement with Size Germany. The information provided is scant and written as an aid to market the products and services. The second is through webpages which have been developed to broadly discuss the survey and provide limited details of the outcomes. For example SizeUK, 2004 (http://www.sizemic.eu/sizeuk.html); Size Germany, (2008) (http://www.hohenstein.de/ximages/1399929_sgabschlus.pdf); SizeUSA, 2004 (http://www.nytimes.com/2004/03/01/us/sizing-up-america-signs-of-expansion-from-head-to-toe.html); AIST Research Institute of Human Engineering for Quality Life - Japan, 2003 (https://www.dh.aist.go.jp/database/fbodyDB/), all provide information of sample size, demographic, gender, amount of measurements taken, brand of scanner used, funding and participating bodies and in some cases but not all general results are provided at a price. In contrast the published details within many manual surveys is considerable and includes valuable information such as: how landmarks are first defined, measurement descriptions, methods for calibrating instruments, and how the participant should be instructed. It appears to be only possible to access small 'tasters' of the 3D scanner outputs, in an aim to encourage the viewer to buy the information, but informative to support the practice of using body scanning for human measurement is very difficult to find.

Much of this technology has been developed outside of the skillsets of clothing product development practitioners and is published in areas often unrelated to product development. There are clear details of how systems of automated landmark location may work in scanning [26], however, these do not accompany the software, so a user is not able to directly understand how a landmark is identified. This reflects a similar lack of clarity in relation to the methods used to locate landmarks when manually measuring the body. [8], However clear and detailed definitions of the landmarks used for manual measurement are provided within literature. As the fundamental first step in measurement, landmark descriptions are crucial to understand what the measurement is and then build on how this relates to product development. The lack of transparency regarding the way 3D scanners locate body landmarks therefore prevents users from being able to fully understand the resulting measurement data, hindering the process of data application within product development.

3. Practical application of body scanning in HE.

The application of new technologies such as body scanning demands the acquisition of a completely new set of skills. Clothing practitioners who adopt scanning for its informative benefits in classifying the body to inform product development must expect a steep learning curve. Not only does scanning operate in a manner slightly different to manual methods, it also requires skillsets which are not traditionally learned during product development. These include a knowledge of manual measurement techniques, manipulation of 3D point cloud data and the operation of engineering software. In addition, the various systems display and analyse the body in a scale and manner considerably different to traditional practice. Whilst the team using the scanner have been keen to develop new skillsets, difficulties have been found when employing these technologies collaboratively with industry partners. There are also further concerns within the research environment regarding the ethical collection and storage of body scan data, which contains sensitive data related to a person's self-identity. The following sections provide reflective details and discussion from the different stages of collection and analysis of the data to help define future considerations. The sections are aligned to the developed practices of using body scanning within HE over the previous decade.

4. Participant data collection and ethical considerations

Whilst body scanners allow the opportunity to capture dimensions of the body which can be analysed within software, some key data is not always embedded with the scans. The body scanner predominantly deals with capturing 3D surface data of the body and whilst the TC2 software enables other data to be collected, this is embedded with the scan and must be recorded manually. Experiences of the team suggest there is some extra data, which it is essential to record alongside the body scans, only some of which it would be suitable with respect of ethical considerations to include alongside the scan. Height and weight represent two key characteristics that are required in the analysis of scan data that are not directly captured through the scan, or not with sufficient accuracy for them to be used reliably. It has been found to be considerably difficult to establish methods of data analysis without the inclusion of height and weight. The following sections describe protocols for collecting and storing the scan data with consideration of its future use and the ethical guidelines as well as responsibilities to the participant.

3.1.1 Collection of key data to accompany scans

During the development of methods for collecting scan data it was established that some form of database would be required to store key personal details. Initially Excel spreadsheets were used, though these were further developed using more advanced database software (Filemaker Pro), to provide a more automated tool to collect these details alongside consent. This enabled the storage of personal details from participants in a password protected environment, separate from the 3D scan data. To enable detailed statistical analysis height and weight were manually recorded from each participant, as these are used within many established methods for dealing with anthropometric data [4, 27] and are essential to the creation of sizing schemes. A means to embed these with the scans is important, though these only need to be embedded with a usable scan and would be best if stored with the scan to be input at the stage of identifying a good scan. Further details which were recorded from each participant are outlined in the following table (*Table 1*)

Table 1: Data required alongside scan capture

Data	Reason for collection
Height	Required for creating subgroups of the data [28, 29]
Weight	Required for creating subgroups of the data [28, 29]
Ethnicity	This will effect proportional division of the body and possibly its shape [27, 30]
Age	Required for creating subgroups of the data [28]
Gender	Required for creating subgroups of the data
Geographic location	Required to fix scan populations by geographic location when analysing data nationally or globally.

Body scanning creates a long term digital record of a person at a fixed time and in a fixed posture, it is anticipated body scans will be used to inform product development and efforts have been made to create large scale repositories of scan data (e.g. isize). It is therefore crucial that key data can be linked to these scans, though clear consideration is required as to how data is stored and linked back to the individual without possibilities of easy identification. It is important that systems are developed to facilitate this approach and would be a natural addition to scan software. The requirement to keep some personal data separate from the scans to retain anonymity and satisfy our ethical obligations to participants required we develop a separate system to collect and store personal data. Using the scanner within academic environments also necessitated that participants were identified as students or not, this removed the assumption that all scans of a certain age group were students and therefore of a certain socio-economic and educational group. This highlights that aside from purchasing scanning technology, robust methods for collecting key demographic details are required and may not always be present with the scanner.

3.1.2 Developing protocols for consent and codifying data

Following development of the database for collecting personal details, methods were developed to create unique codes for each scan participant in order to maintain anonymity but still preserve a clear link between the different data types (scan and personal information). To inform participants about the scan process and resulting data, a detailed video of the process, alongside an information sheet are provided to participants. Each participant is then required to sign a consent form, detailing how the data would be used assuring anonymity, in line with typical academic ethical protocols. The collection of consent provided the opportunity to generate each participant's unique code to allow the individual scans to remain anonymous, current scan systems provide means to name the scans, however there is no guidance on what format should be used. Experiences of storing and analysing scan data suggested that some key information was important within the code to enable key aspects to be identified when all that was present was a copy of the scan. A unique eight figure code was developed that included key details to enable scans to be sorted, selected and contextualized without reference to accompanying personal details. Gender was coded as M or F, experience had shown that within the scan environment not all data could be discerned visually as belonging to either gender and having to check raised a number of issues, this was especially so when participants morphology was altered through sports participation or restrictive clothing. Age was also recorded to enable grouping of data and whilst it is accepted that age would affect body size and shape, this again was not easily and accurately determinable from visual inspect of the scans. Finally ethnicity was included in the name, again this removed presumptions about appearance of different ethnicities, though it raised issues about which guidance would be used to provide the classification. The initial first level NHS classification were selected as appropriate and provided the means to identify broad ethic groupings which had been shown to have some potential effect on segment lengths [27].

3.1.3 Assessment of scan data

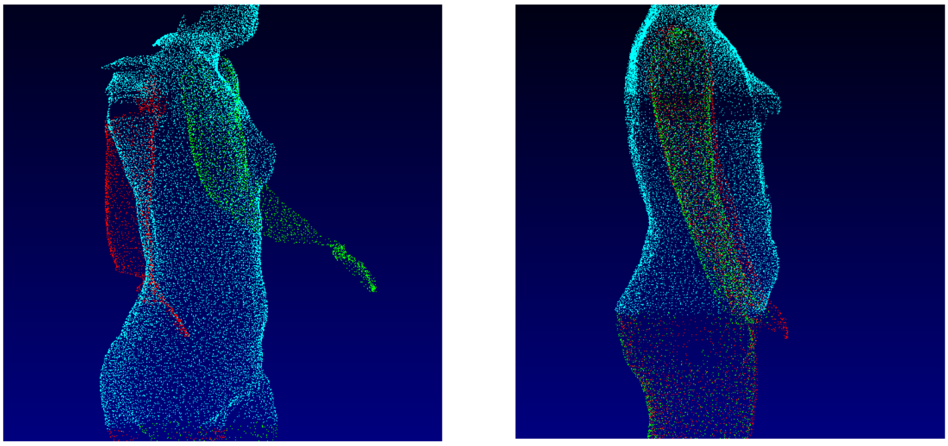
Alongside the collection of personal details, the processes of collecting scans needed clear protocols, methods for collecting height and weight were standardised in accordance with existing guidance, though it is recognised these may vary by discipline. The nature of the body scanner and the accessibility to a number of operators required strict guidance to ensure data was collected comparably between them to have least impact on the accuracy of the data when investigated as a group. This raises issues about standardisation of practice, when data may be used as part of a larger group collected using different protocols. Any standard introduced however must be sensitive to equipment, purchased separately from the scanner and the particular skillsets of the increasingly diverse operator of this technology.

3.2 Scan data collection and analysis

Once the process of collecting consent, participant details and coding scans is established the stage of actually collecting scan data from participants can be undertaken. This begins the process where skillsets and new methods of data interpretation is required A number of considerations are outlined here.

3.2.1 Determination of a usable scan

Scan manufacturers have developed some detailed and robust methods for capturing the scan, including standardisation of posture. However, during scan capture it is not unusual for difficulties to arise in determining a suitably detailed scan, without excess noise or postural issues. The first stage of assessing the scan is visually to check that all parts are present and that surfaces do not show unexpected deviations. These are not always immediately visible, for instance forgetting to tie up long hair may not make the scan capture fail, but may result in a scan where complete data cannot be extracted. Currently there are no documented methods for assessing scans and few automated checks within the system to highlight errors of a small nature. Protocols were developed to ensure that each scan was rotated to be viewed from different angles to check the surfaces and running an automated measurement extraction helped to visual potential problems through misplaced landmarks.



Sample of poor point cloud data on the scan

Difficulties placing crotch point and handling dark colours on the bra

Figure 1 Examples of problematic scan data

3.2.2 Establishing which data to extract from participants

The automated extraction facilities within the TC2 software provided a number of flexible definitions of measurements and included details of those used in national surveys. However, there were no measurements clearly aligned to existing manual standards and it became increasingly evident that body scanning using automated tools does not establish and extract measurements in a manner comparable in many cases to established manual methods. Having a list of measurements set up in accordance with existing standards [16, 31] would help initially integrate this technology into existing, even a simple translation between these and standards when directly comparable in method would help with the translation of skills. What is evident is that body scanning as indicated previously [9] provides a greater depth of data than existing manual systems and even overcomes difficulties of obtaining measurements which required a default to proportionally derived measurements within product development methods [5, 32]. Once methods of data extraction were established, the difficulty of describing the collected data, its context in terms of limited familiarity with measurement and even existing industry practices needed to be overcome. Without explicit details of landmark definitions used in body scanning it was often difficult to relate measurements directly to those with which participants or users were familiar. The mistaken notion that scanners provide comparable data to manual measurement made its application difficult in certain circumstances and highlighted the vagaries of practice existing in current methods of measurement. Further development and standardisation is required to help those experiencing scanning gain meaningful data from the process and so encourage greater uptake with the technology.

3.2.3 Cleansing data

Data collected from body scanning does not have the checks which occur during manual collection and to date many of the methods for error checking used in manual surveys do not currently exist within the scanning systems. This includes tolerances on measurements and the ability to check dimensions during data collection This is in part down to the sheer volume of data which can be collected. However for a number of reasons erroneous data can be collected, this may be the misplacement of landmarks due to poor point clouds, or measurement paths which are not sufficiently tied to the body surface. Issues with landmark location within the Tc2 software was found to be effected by body shape [33], though how this was dealt with, by point modification or altering definitions is not detailed. The lack of explicit information on how to deal with scan data removes the opportunity to develop structured and standard methods for dealing with them in future. During the process of scan cleansing it may necessary to completely delete some scans. As a consequence, new protocols were developed for capturing multiple scans and identifying those which are deemed usable. The TC2 software has a facility to rescan using the same name and appending a letter after the scan which helps in the process of identifying a good scan of an individual from a batch. However as multiple scans cannot be opened simultaneously and the best one identified, the process of establishing the best scan is not as streamlined as users would like. Often modification is required which involves manual manipulation of the landmark itself. To achieve this end clear documentation has had to be developed by the team to guide on landmark modification and ensure this process has some degree of rigour between users. However, the process of adjusting landmarks requires a familiarity with anatomy and manual measurement techniques as well as product development to ensure decisions on the placement of landmarks is suitably informed. The difficulty of determining how the landmarks are defined within the software makes it necessary to reflect manual definitions and it must then be hoped methods of defining these virtual landmarks are continuing to replicate manual methods. A common issue is found with the placement of the front underarm points, this necessitated that a definition be created which should describe the placement of this point. In manual measurement various tools have been used to define this landmark [6, 8] which equates to the crease formed in the axilla when the arm is abducted to the body and the skin folds just above the musculature controlling adduction. However most methods of manual landmark location are developed as a practitioner skill, with few examples of detailed descriptions of landmarks and their methods of location [8].

When adjusting the underarm landmark which is visually assessed to be misplaced, a judgement must be made as to where the landmark would lie if it were manually positioned on the body;this is complicated as the scan position requires the arm be abducted from the body. An example of the process can be seen in Figure 2.The judgement required to reposition this landmark must be made without all the visual and tactile cues of manual methods and in a scale much smaller than lifesize, as well as scant detail from the software as to what this landmark was originally positioned with reference to.

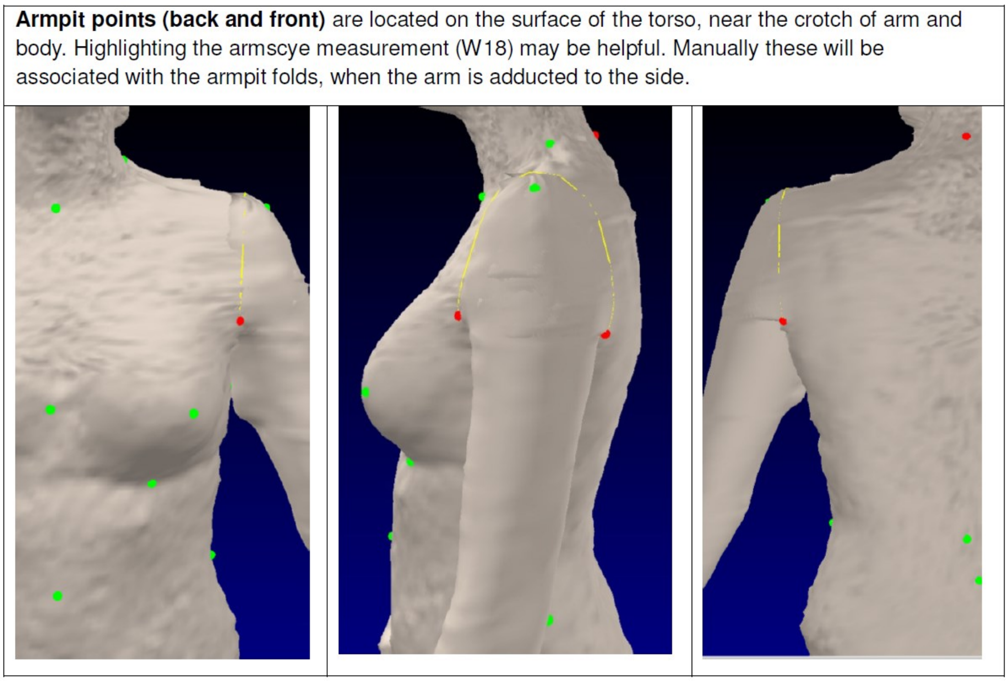


Figure 2: Visual guidance provided on correct location of the armpit point

The necessity to create visual guidance on what is considered good landmark placement to guide new users, highlights an area of development that is key to the success of using automated measurement within body scanning with varied user groups. If persistent errors cannot be checked and amended against some standards there is the possibility of lots of erroneous data being generated by the multiple users of this technology.

3.3 Research with body scan data

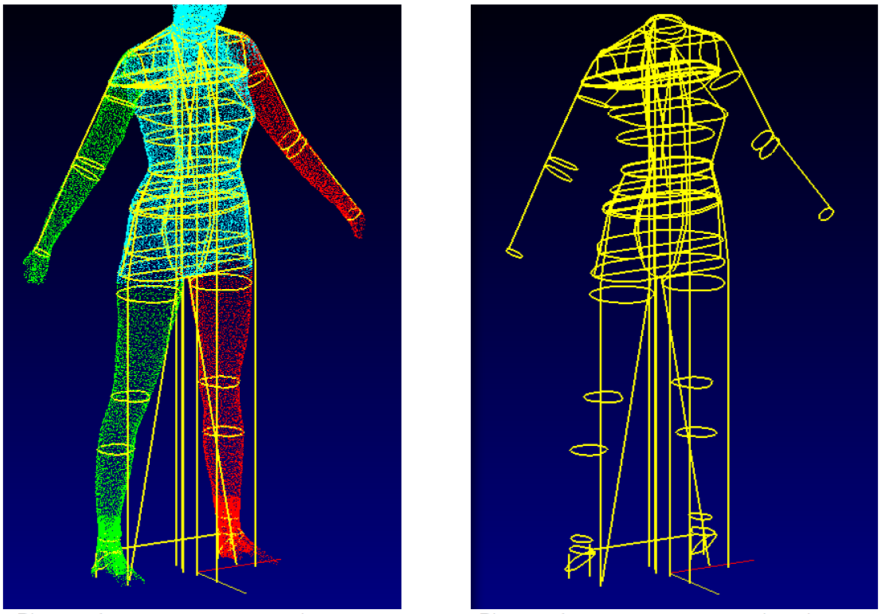
Having access to body scanning technology has provided opportunities to create new researchpathways, both concerned with understanding the data created, as well as providing new data to help understand the body within product development. The scanner has also been found to be a useful collaborative tools providing opportunities for engineers, psychologists, nutritionists and product developers to explore the body and its relationships. However, this also necessitates that there is a full understanding of the equipment and a means to explain its methods of establishing measurements and the meaning of the data presented within the software.

3.3.1 What to give participants and how

The body scanner provides a unique output for many participants, on screen they can view their bodies in 3D from a number of angles and printed 2D outputs provide a detailed snapshot of the bodyusually representing a front and side view. This visual data can be extremely informative, but often has little cultural context, due to the limited use of scanning for the general population. Further difficulties are faced when providing measurement data to participants or industry partners, due to the differences between methods of scanning and manual measurements, the data is not directly comparable. It is therefore difficult to provide an output with a clear definition that aligns to most peoples' historic experience. However explaining to participants the nuances of this becomes prohibitive, they want data which will help them make or select product and they often will not want to contend with the idea of their being more than one definition for a measurement even though it is named the same Further changes in product development practice which see industry professionals using garment measurements with no direct relation to body dimensions [34] makes the situating of scan data in their practice difficult. In certain cases the team had developed outputs which signified measurements that could be used in sizing selection, though often participants were as interested in the seeming variance between left and right sides as they were with the product related data. Without standardisation of practice and a common set of definitions between scanner systems it is difficult to see how this will be avoided in future, it is clear however that existing standards for body scanning measurement [16] are limited in their ability to address these issues, which have a direct bearing on body scanning as a usable tool that participants will engage with during product development. It is not unusual for comments to be made about comparison of manual and scanner measurements; however, this often fails to recognise the advantages of scanning and limitations of manual methods. Manual methods for product development require many dimensions be determined proportionally due to their difficulty of capture with the tools available. Body scanning in contrast provides the opportunity to capture dimensions which have much greater context in developing products and can overcome many limitations of manual methods.

3.3.2 Measurement networks

Body scanning by its very nature requires that many measurements are related during their definition, this creates a clear measurement network, which better relates to product development than existing manual approaches (Figure 3). Products which are worn are usually formed of complete surfaces which cover areas of the body, these relate circumferences by surface lengths and can be more readily related to a measurement network, than manual methods which often deal with measurement in isolation.



Picture of measurement network on scan | Picture of measurement network on its own

Figure 3: Measurement networks

4. Conclusions and future considerations of body scanning for product Development

Whilst there is a clear need to for greater interventions and innovations to enable body scanning to be accessible to more practitioners and those in HE environments, it does provide some clear solutions to limited manual practices. There is a need to develop measurement definitions built on the principals of measurement networks and with sufficient levels of information for data to be understood as with historic manual surveys. The following considerations are important to establish prior to implementations body scanning in an HE environment and may have application to users outside of this. 1. Methods need to be developed for collecting demographic details to contextualise the scan data, these include at a minimum height, weight, age and ethnicity; 2. Methods of codifying data are required to protect anonymity but allow informed storage and management of data; 3. Clear understanding of automated methods are required and clear definitions of measurements should be documented and where possible include details of virtual landmarks. 4. Robust methods must be developed for the analysis of data for accuracy and clear procedures for amending scans. 5. Training should be sought in software allowing analysis and processing of the scan data outside of the accompanying software packages.

Fundamentally this technology will be more successful if there is clear and open discussion between developers and users to ensure it can fulfil its potential and all stakeholders (suppliers, users and participants) can all benefit. Some further discussion of the considerations highlighted in the paper are in the sections below.

4.1 Standardisation of data collection

It is important that scan manufacturers give further consideration to the key characteristics/demographic details that are important to capture to enable scan data to have the application. Further to this means of coding data need to be considered and some efforts made to ensure that all users can collect data which is meaningful yet retains anonymity of the participant.

4.2 Development of new skillsets

The knowledge base indicates research has developed and explored a variety of algorithmic methods enabling the software programmes within bodyscanning systems to locate and/or place landmarks over the virtual skin surface. The research is from a wide variety of disciplines including anthropometrics [35]); clothing development; computer science [18, 36] and statistics, indicating skillssets from interdisciplinary fields will be required to work together to effectively develop the technology further. This expansion of skillsets required to successfully operate body scanners suggests those being taught product development need to gain further familiarity with technical engineering software principals and techniques to fully benefit from body scanning technology. This requires that discipline specific practices are shared and made more accessible, so computer programmers can better understand product development practices and those involved in product development can better engage with methods of automated analysis of the body in electronic environments.

4.3 Enhanced tools for analysis

Whist existing systems of scan analysis provide good opportunities to investigate data for product development, detailed analysis often requires the use of engineering software outside of the skillsets of many product developers. Developments in visualisation within the accompanying software tools would help both the exploration of data for research, as well as the ability to communicate data to participants. Some considerations here are, the ability to open multiple scans, align them and visually compare them, this would help show participants how they compare to each other as well as to a standards, like a scanned dress form, further means to show cross sections and planes through the body at different locations would enhance how a participants can engage with the data.

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44 Appendix AJ

44.1 Private email correspondence

RE: Thanks for your support!
Simeon Gill [simeon.gill@manchester.ac.uk]

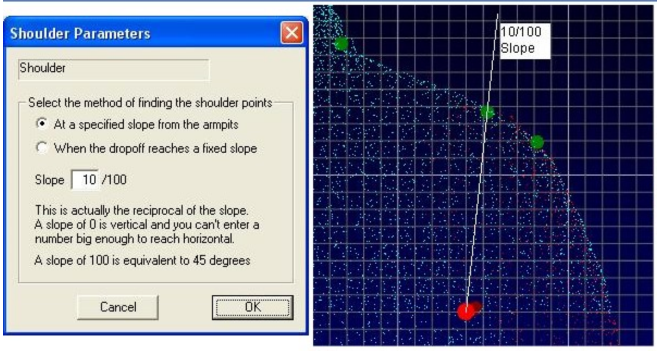
You replied on 17/07/2017 14:59.

Sent: 14 July 2017 17:28
To: Paula Wren
Cc: Kathryn Brownbridge; Phoebe Apeagyei
Attachments: P Wren Thesis revisions r~1.docx (2 MB) [Preview on web]

Hi Paula

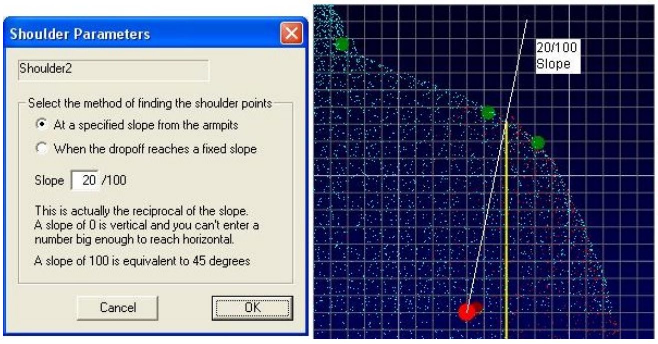
I have had a chance to go over your draft and revisions and have made some suggestions in the attached. I have added a direct response regarding shoulder landmarks and some considerations related directly to the thesis text at the end.

Previous | **Return to top of MEP editor tutorial** | **Next**



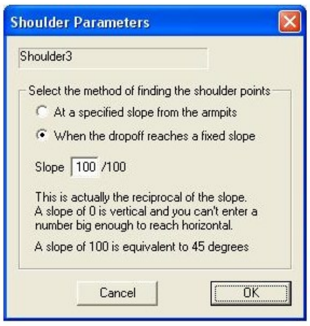
Default Shoulder

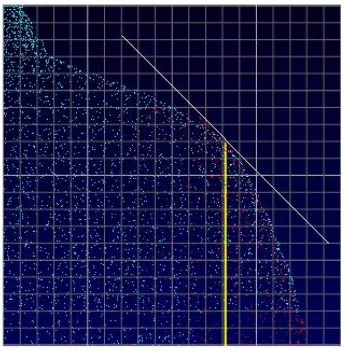
This is the default shoulder. It is found on a plane running through the armpit and at a slope of 10/100. The plane is parallel to the X axis (the one running back to front). The shoulder is the highest point on that plane.



Shoulder 2

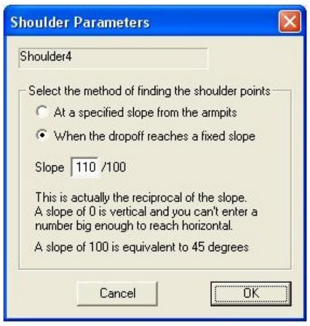
This is shows how changing the slope affects where the shoulder is found.

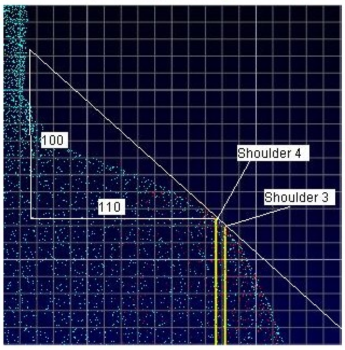




Shoulder 3

This is a different way of finding the shoulder. Here we have drawn a line at 45 degrees (slope of 100/100) move it toward the torso and where it hits the torso is the shoulder.





Shoulder 4

This shows how changing the slope affects where the shoulder is found when the dropoff method is used.